APPENDIX E
FIELD STANDARD OPERATING PROCEDURES

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The following Standard Operating Procedures (SOP) were developed for use by Titanium Metals Corporation environmental staff and contractors. These SOPs are based upon publications prepared by the American Society for Testing and Materials (ASTM), Federal regulations and guidance documents, Basic Remediation Company's May 2006 Field Sampling and Standard Operating Procedures, Tetra Tech EMI's Standard Operating Procedures, and professional opinion.

Table 1 provides an index of the SOPs that follow. It should be noted that this list does not address all sampling scenarios or impacted media. Project-specific sampling and analysis plans will include sampling rationales, methods, and detailed procedures, as required.

TABLE 1
STANDARD OPERATING PROCEDURES

SOP No.	SOP Title	ASTM No.
General (SOP-1 through SOP-49)		
SOP-1	Preparation and Review of Written Documents	--
SOP-2	Site Reconnaissance and Characterization	--
SOP-3	Field Documentation	--
SOP-4	Sample Management and Shipping	--
SOP-5	Investigation Derived Waste Management	--
SOP-6	Field Equipment Operation and Calibration	--
SOP-7	Equipment Decontamination	--
SOIL (SOP-50 through SOP-99)		
SOP-50	Soil Sampling	D1452, D1586, D1587, D3550, D4220, D4547, D4700, D5451
SOP-51	Drilling Methods	D6914, D1452, D3441, D5781, D5782, D5783, D5784, D5872, D5876, D5875
SOP-52	Borehole Logging	D2488
SOP-53	Soil Sampling for VOCs Using EnCore Samplers	--
SOP-54	Photoionization Detector	--
SOP-55	Borehole and Well Abandonment	D5299
WATER (SOP-100 through SOP-149)		
SOP-100	Groundwater Monitoring Well Design and Installation	D5092
SOP-101	Groundwater Monitoring Well Development	D5092
SOP-102	Aquifer Testing Methods	--
SOP-103	Groundwater Sampling Using Micropurge Technology	D1293, D888, D1125, D1889
OTHER MEDIA (SOP-150 through SOP-199)		
SOP-150	Concrete Sampling for PCB	--

1.0 INTRODUCTION

Any environmental investigation where data collection is conducted requires the preparation of written documents. These documents may range in complexity from simple letter reports to multivolume reports composed on a variety of media. A set of procedures was developed to ensure we meet customer requirements and technical standards for all written work produced. One of the quality system elements required by the *American National Standard: Quality Systems for Environmental Data and Technology Program – Requirements with Guidance for Use* (ANSI/ASQ E4-2004) is deliverable reviews.

1.1 PURPOSE

This Standard Operating Procedure (SOP) was developed to promote uniformity in the presentation of environmental data—including authoring, reviewing, and publishing reports that may contain information in text, tables, databases, figures, and drawings.

1.2 SCOPE

This SOP applies to the entire team and supporting staff involved with the preparation of written project documents. Each written document will be reviewed and prepared according to the basic quality assurance (QA) process set forth in the SOP; however, based on the complexity or intended use of the document, additional QA requirements may be implemented as necessary.

1.4 REFERENCES

American National Standard Institute/American Society for Quality (ANSI/ASQ). 2004. *American National Standard: Quality Systems for Environmental Data and Technology Program – Requirements with Guidance for Use.* ANSI/ASQ E4-2004.

2.0 METHODS AND PROCEDURES

This section includes the procedures to be followed when authoring, reviewing or publishing written documents.

2.1 DOCUMENT AUTHORSHIP

A suitable technical author must be selected for each written document produced. Determination of document authorship is the responsibility of the Program Manager with approval by the client. Ideally, the author is an active member of the project team already approved by the client. However, in cases where an unusual expertise is required, the Program Manager can select an additional staff member who is experienced in that technical area to author the document.

It is the responsibility of the author to assimilate and evaluate all relevant data to support the written text and especially any conclusions that are formulated. Larger complex documents may require the use of several authors in their respective areas of expertise. In this case, one author should be assigned the primary author and be responsible for coordinating the assimilation of all text and data from other authors into the final document.

When all materials, text, and data are assimilated into the document, the document must undergo a minimum review process. This process is discussed in the following sections.

2.2 DOCUMENT REVIEW

For this project, some documents are only delivered to the client (TIMET), whereas others that include environmental data and findings are generally delivered first to the client (TIMET) then to the regulating body (State of Nevada Division of Environmental Protection [NDEP]). The review process for each type of deliverable are discussed below.

All written documents will have the following minimum reviews:

1. Technical review
2. Editorial review
3. QC review

Technical reviews are conducted by experienced personnel with direct knowledge of the technical areas addressed by the deliverable. The purpose of the technical review is to evaluate the overall technical quality of the deliverable. This is done by evaluating whether the project background is presented appropriately; the data collection and discussion are sufficient to support the conclusions; the overall technical approach presented in the deliverable is valid; the conclusions and recommendations are justified; and the deliverable fulfills the requirements of the project objectives. Multiple technical reviewers may be used for deliverables that have significant content in more than one technical area (for example, geology, chemistry, and engineering). Prior to writing the document, input from the editor and QC reviewer may be solicited to aid in organization and formatting of the document.

Editorial reviews are conducted by technical personnel (either specially trained as an editor or selected as adept in conducting editorial reviews). The reviewer evaluates the editorial quality of written deliverables—whether the purpose is stated clearly; the discussion is coherent and consistent; the deliverable is clear, readable, and well-organized; data are clearly presented in tables and figures; and an appropriate summary is included. In addition, the editor may help authors plan and organize documents before the writing process begins.

QC reviews are completed by a senior member of the project team or other person designated by the Program Manager. The QC review is a final check on each deliverable before it is submitted to the client. The QC reviewer focuses on ensuring that (1) technical and editorial review comments on the deliverable have been addressed, (2) the deliverable is consistent with overall program and project goals, and (3) the deliverable does not contain assertions or statements that could expose the client to excessive risk. The QC reviewer can require additional technical or editorial reviews of the deliverable if questions remain about technical or editorial issues.

Documents that are further delivered to the NDEP require an additional client review (which may include the environmental manager for the client and/or legal council) and review by a certified environmental manager. No document may be submitted to the regulatory body without first obtaining approval from the client and a certified environmental manager, who is required to sign a jurat stating, in essence, that the document has been prepared according to current standards of the profession and that comply with all applicable federal, state, and locate regulations.

In some cases, more or less stringent review levels may be appropriate for deliverables. The program manager and project team, along with the client's approval, may agree on an appropriate level of review during the planning stages for each deliverable.

Special cases, such as engineering drawings, may require review and certification by a licensed or registered professional in a given industry. These reviews and personnel will be identified during the planning stages of the project.

2.3 DOCUMENT PUBLICATION

Documents may be published in several formats (or combinations thereof): (1) bound hardcopy, (2) electronic on CD, and (3) electronic by internet. Upon completion of all required reviews, the author will present the final document and all appendices, and attachments to the document control coordinator (production manager). The source files for the document are carefully converted to portable document format (PDF) by Adobe Acrobat® and compiled into as few files as feasible. Hardcopy production is conducted using high-quality printers and copies or subcontracted to a reproduction firm capable of producing high-quality prints. Subcontractors are often used for reproduction of color prints or oversized drawings. Before incorporation into the final deliverable, a review of subcontracted materials is conducted.

Each hardcopy document may also include electronic databases or large appendices that are not otherwise suitable for paper production. All CD or DVDs are prepared and reviewed prior to inclusion in the larger hardcopy deliverable.

All documents are also completely produced in electronic format (PDF) and delivered to recipients on CD or DVD. In addition, an electronic copy of the deliverable is archived in the document control center for this project.

DISCLAIMER
This SOP provided general guidance for TIMET contractors and subcontractors for technical issues addressed during environmental site investigation and remediation activities. It is noted, however, that each site and project is unique and these guidelines are not a substitute for common sense and good management practices based on professional training and experience. In addition, individual contract terms may affect the implementation of this SOP. TIMET contractors reserve the unrestricted right to change, modify or not apply these guidelines in their sole, complete, and unrestricted discretion to meet certain circumstances, contractual requirements, site conditions, or job requirements.

1.0 INTRODUCTION

The site reconnaissance and characterization (investigation) will involve a visual site inspection to evaluate the presence of conditions at hazardous sites that may pose potential health and safety hazards to employees engaged in field work. These conditions may include physical hazards, insufficient oxygen levels, exposure to flammable vapor levels, high or toxic concentrations of gases or chemicals, or high levels of radiation. Evaluation of health and safety hazards consists of (1) reviewing and summarizing existing site data and preparing a site health and safety plan (HSP); and (2) performing the investigation using monitoring or sampling equipment.

1.1 PURPOSE

This Standard Operating Procedure (SOP) was developed to promote uniformity in investigating and evaluating potential health and safety hazards at sites before employees begin field work.

1.2 SCOPE

This SOP applies to the investigative teams conducting investigations at hazardous sites to determine potential health and safety hazards that company personnel may be exposed to during field work. Each investigation will consist of a visual site inspection, the use of monitoring or sampling equipment, and the use of appropriate personal protective equipment.

2.0 METHODS AND PROCEDURES

The procedures to be followed when conducting an investigation are discussed in the following subsections.

2.1 HEALTH AND SAFETY PLAN

Before an investigation may begin, a site-specific HSP must be completed that satisfies the requirements of the Occupational Safety and Health Administration as defined in the Code of Federal Regulations (29 CFR 1910.120). The HSP must be reviewed and signed by all members of the investigative team prior to arriving on site. Members of the investigative team must comply with the site HSP, which will specify the necessary personal protective equipment.

2.2 VISUAL SITE INSPECTION

The investigative team will visually inspect the site during a walkover of the site. Ambient air monitoring will be conducted if needed. The subsections below discuss establishing a staging area, evaluating potential health and safety hazards, and decontaminating equipment.

2.2.1 Establishing a Staging Area

The investigative team will prepare for the visual site inspection at a staging area judged to be clean on or near the site. This area will be used to don personal protective equipment, zero instruments, take background readings if needed, and serve as the decontamination center. The staging area should be upwind of potential contaminant sources.

2.2.2 Evaluating Health and Safety Hazards

The entire site, including bulk storage vessels, confined spaces, ponds, drum storage areas, and other points of interest will be monitored and sampled as needed to detect the presence of potentially hazardous conditions (for example, oxygen deficiency, explosive atmospheres, high vapor or radioactivity levels, or physical hazards). Locations of health and safety hazards or instrument readings exceeding background readings will be written in a field logbook. Conditions that may lead to potential health and safety hazards are discussed in the following paragraphs. Background information about hazardous materials or waste handled at the site will be used to determine if any or all of the conditions described below need to be monitored.

1. **Oxygen Deficiency:** The entire site, but particularly confined spaces, may be monitored for oxygen deficiency. Readings should be taken at ground, waist, and head levels. Any area with an oxygen level of less than 19.5 percent must be avoided. Confined spaces must be entered only by investigative team members using air-supplied respirators. Under no circumstance should an air-purifying respirator be used in confined spaces or oxygen-deficient atmospheres. An additional note of caution is that an explosivity meter will not function properly in oxygen-deficient atmospheres. An oxygen-deficient atmosphere may be explosive, but the explosivity meter will not respond properly in this atmosphere. Treat oxygen-deficient atmospheres as potentially explosive.

2. **Explosivity:** Continuous ground, waist, and head level readings may be obtained in confined spaces or areas where explosive gases are suspected. If readings approach or exceed 10 percent of the lower explosive limit (LEL), extreme caution should be used in continuing the investigation. If readings approach or exceed 25 percent of the LEL, the investigative team should withdraw from the area immediately. Be aware that explosivity meters will go off scale and readings will drop as the concentration of explosive gases increases. Before resuming any on-site activities, the investigative team should consult with fire protection experts or the local fire department and then develop explosion prevention procedures for safe site work. (Refer to the discussion of oxygen-deficient atmospheres and the explosivity meter caution in the Oxygen Deficiency paragraph above).

3. **Chemical Vapors:** Organic chemical vapor levels may be monitored using an organic vapor monitor. Inorganic chemical vapors may be monitored using colorimetric indicator detector tubes or compound-specific detectors. When working in an unknown environment (for example, an environment in which atmospheric compounds are not known) and wearing air-purifying respirators, vapor concentrations cannot exceed 5 parts per million (ppm) for a 5-minute time weighted average period. If vapors exceed 5 ppm, the site must be evacuated. Re-entry will only be allowed with the use of air-purifying respirators. Atmospheric concentrations cannot exceed 500 ppm for continuous site work to occur. If atmospheric concentrations exceed 500 ppm, the site should be evacuated and appropriate experts contacted to determine additional personal protective equipment or other safety precautions required for continued site work.

When working in a known environment (for example, atmospheric compounds are known), vapor concentrations cannot exceed the threshold limit value for the compound if no respiratory protective equipment is being used. Air-purifying respirators may be worn only when the vapor concentration is below the recommended level of the respirator cartridge being used and below the immediately dangerous to life and health concentration. Areas in which high levels of vapor concentrations are encountered should be avoided if possible. When specific chemical vapors are known to exist on site, colorimetric indicator detector tubes specific to those chemicals should be used.

4. **Radioactivity:** The site may be monitored for radiation levels. If radioactivity levels approach 10 milliroentgen/hour (mR/hr), a detailed radiological site survey should be conducted. If radioactivity levels are greater than 10 mR/hr, the site should be evacuated and the assistance of a radiation health physicist should be obtained prior to site re-entry. Normal background radioactivity levels are about 0.02 mR/hr; however, levels up to 10 mR/hr are acceptable for investigations of short duration.

5. **Physical Hazards:** Physical hazards may include electrical hazards (down or exposed power lines); unsafe structures or deteriorated buildings, tanks, supports, or beams that are in the process of collapsing (or based on physical evidence may collapse at any time); pits (open or closed); trenches; buried tanks or structures; or any other type of elevated, surface, or subsurface structure that may fall, cause an employee to trip or fall, or cause an employee to fall into it. Other physical hazards of concern may include heavy equipment (backhoe, drill rig, and so on); biological hazards (plants and insects); noise hazards; and weather (lightning, heat, and cold stress). All such hazards should be identified and described in a field logbook.

2.2.3 Decontaminating Equipment

Disposable personal protective clothing should be worn during an investigation. Prior to leaving the site, all disposable clothing will be placed in large industrial-grade plastic bags or 55-gallon drums. Boots and other nondisposable items will be decontaminated in the staging area using portable water basins and industrial-grade, water-based detergents. Decontaminated equipment and clothing will be placed in plastic bags before investigators leave the site. All contaminated equipment will remain on site.

3.0 CAUTIONS

Seemingly safe sites or situations may still present life-threatening conditions. Even the best monitoring equipment cannot replace astute observation and common sense. Be alert and aware of surroundings and conditions at all times.

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common sense and good management practices based on professional training and experience. In addition, individual contract terms may affect the implementation of this SOP. TIMET contractors reserve the unrestricted right to change, modify or not apply these guidelines in their sole, complete, and unrestricted discretion to meet certain circumstances, contractual requirements, site conditions, or job requirements.

1.0 INTRODUCTION

This Standard Operating Procedure (SOP) is a general reference for the required documentation to be completed by company personnel during field investigations. Subject to the requirements of the sampling and analysis plan, records in the form of field logbooks, reports, and forms should normally be completed for the various field activities. Records should be maintained on a daily basis as the work progresses, and should contain enough information to allow the activities to be completely reconstructed. All field records must be accurate, objective, and legible. The field logbook should contain detailed records of all the field activities, interviews of people, and observations of conditions at a site. Entries should be described in as much detail as possible, so that personnel can accurately reconstruct the activities and events which have taken place during field assignments. Field logbooks are considered accountable documents in legal proceedings and may be subject to review. Therefore, the entries in the logbook must be accurate, detailed, and reflect the importance of the field events.

1.1 PURPOSE

The purpose of this SOP is to provide guidance to ensure that field documentation for any field activity is correct, complete, and adequate. Logbooks and field forms are used for identifying, locating, labeling, and tracking samples. A logbook should document any deviations from the field sampling and analysis plan, quality assurance project plans, and health and safety plans. A complete and accurate logbook also aids in maintaining good quality control. Quality control is enhanced by the proper documentation of all observations, activities, and decisions.

1.2 SCOPE

This SOP establishes the general requirements and procedures for adequately documenting field activities. Primary field activities are covered below. It should be noted that additional field forms may be utilized during a field event. These forms and their use will be covered within their applicable sampling and analysis plan or SOP.

2.0 FIELD DOCUMENTATION PROCEDURES

Field documentation serves as the primary foundation for all field data collected that will be used to evaluate the project site. Field documentation must be accurate, legible, and written in indelible ink. Mistakes are to be crossed out with one line, dated, and initialed. Skipped pages or blank sections at the end of a page should be crossed out with an “X” covering the entire page or blank section, dated and initialed. The person making the correction should write “No Further Entries,” and date and initial the page. The responsible field team member should sign and log the date and time after the last entry for the day. To further assist in the organization of the field books, logs, or forms, the date and the activity description should be written at the top of each page. In addition, all original field documentation should be included with the project files.

2.1 FIELD LOGBOOKS

Field logbooks should be bound with water resistant and acid-proof covers; they should have preprinted lines and wide columns. They should be approximately 7 1/2 by 4 1/2 inches or 8 1/2 by 11 inches in size. Loose-leaf sheets are not acceptable for field notes. If notes are taken on loose paper, they must be transcribed as soon as possible into a regular field logbook by the same person who took the notes.

A field logbook should be completed for each operation undertaken during the investigation, such as field team leader (FLT) notes, drilling, collection of samples, monitoring well installation and development, etc. The logbook serves as a diary of the events of the day. Field activities will vary from project to project; however, the concept and general information to be recorded will be generally consistent. The following sections describe the minimum information that should normally be recorded.

FTL Logbook

The FTL's responsibilities include the general supervision, quality assurance, support, and coordination of the various field investigation activities. Records of the FTL's activities, as well as a summary of the field team's activities, are maintained in a logbook. Items to be documented include the following:

- Record of tailgate meetings
- Personnel and subcontractors on job site and time spent on the site
- Field operations and personnel assigned to these activities
- Site visitors
- Log of the FTL's activities—time spent supervising each operation and summary of daily operations as provided by field team members
- Problems encountered and related corrective actions
- Quality control activities—e.g., decontamination procedures, QA/QC samples taken, calibration of field equipment
- Deviations from the sampling plan
- Records of communications—discussions of job-related activities with the client, subcontractor, field team members, and project manager
- Information on addresses and contacts
- Record of invoices signed and other billing information
- Field observations

Geologist/Sampling Team Logbook

The geologist or sampling team leader is responsible for recording the following information in the logbook or on the appropriate field form/log. If a field form or log is used to record the information it should be referenced in the logbook.

- Health and safety activities
  - Calibration records for health and safety equipment (type of photoionization detector [PID])
  - Calibration gas used and associated readings, noise dosimeters, etc.
  - Personnel contamination prevention and decontamination procedures
  - Record of daily tailgate safety meetings

- Weather

- Calibration of field equipment

- Equipment decontamination procedures

- Personnel and subcontractors on the job site and time spent on the site

- Site name and well or soil boring number

- Drilling activities
  - Sample location (sketch)
  - Drilling method and equipment used
  - Borehole diameter
  - Drill cuttings disposal/containerization (number of drums, roll off-bins, etc.)
  - Type and amount of drilling fluids used (mud, water, etc.)
  - Depth and time at which first groundwater was encountered, depth to water at completion of drilling, and the stabilized depth to water—absence of water in the boring should also be noted
  - Total drilling depth of well or soil boring
  - Type and amount of materials used for well installation
  - Well construction details—depth of grout (mixture, weight), bentonite seal, filter pack, etc. (include type and amount used, calculate estimated amount that should be used)
  - Type and amount of material used to backfill soil borings
  - Time and date of drilling, completion, and backfilling
  - Name of drilling company and driller

- Sampling
  - Date and time of sample collection
  - Sample interval
  - Types of samples taken
  - Number of samples collected
  - Analyses to be performed on collected samples

- Disposal of contaminated wastes (personal protective equipment, paper towels, Visqueen®, etc.)
- Field observations
- Problems encountered and corrective action taken

2.2 BORING LOGS

The preparation of drill logs is the responsibility of the field geologist(s). A detailed description of well logging is provided in the SOP for Borehole Logging, SOP-52. A drilling log template is provided as an attachment to SOP-52. At a minimum, the following basic information should be recorded on the log:

- Project and site name
- Name of driller and drilling company
- Type of drill rig used
- Boring identification number
- Drilling and backfilling dates and times
- Reference elevation for all depth measurements
- Total depth of completed soil boring
- Depth of grouting, sealing, and grout mixes
- Signature of the logger
- Description of unconsolidated materials
  - Geologic lithology description
  - Descriptive Unified Soil Classifications System (USCS) classification
  - USCS symbol
- Color (use appropriate soil color chart)
  - Penetration resistance (consistency or density)
  - Moisture content
  - Grain size information
  - Miscellaneous information (odor, fractures, visible contamination, etc.)
- Description of consolidated materials
  - Geologic rock description
  - Rock type
  - Relative hardness
  - Density
  - Texture

  - Color (use appropriate rock color charts)
  - Weathering
  - Bedding
  - Structures (fractures, joints, bedding, etc.)
  - Miscellaneous information (presence of odor, visible contamination, etc.)

- Stratigraphic/lithologic changes; depths at which changes occur

- Depth intervals at which sampling was attempted and amount of sample recovered

- Blow counts, if applicable

- Depth intervals from which samples are retained

- Depth at which first groundwater was encountered, depth to water at completion of drilling, and the stabilized depth to water. The absence of water in the boring should also be noted.

- Loss and depth of drilling fluids, rate of loss, and total volume of loss, if applicable

- Use of drilling fluids, if applicable

- Drilling and sampling problems

- PID readings

2.3 WELL CONSTRUCTION RECORD

The preparation of well construction diagrams is also the responsibility of the field geologists. This topic is further discussed in the SOP for Groundwater Monitoring Well Design and Installation, SOP-100. A well construction record is provided as an attachment to SOP-100. At a minimum, the following basic information should be recorded on the log:

- Project and site name

- Well identification number

- Name of driller and drilling company

- Depth and type of well casing

- Description of well screen and casing

- Borehole diameter

- Any sealing off of water-bearing strata

- Static water level upon completion of the well and after development
- Drilling and installation dates
- Type and amount of annulus materials used; depth measurements of annulus materials
- Other construction details (filter pack type and interval, location of centralizers, etc.)
- Surface elevation and reference elevation of all depth measurements

2.4 GROUNDWATER SAMPLING AND DEVELOPMENT LOGS

The groundwater sampling and development log is the responsibility of the sample team leader. This topic is further discussed in the relevant SOPs for Groundwater Monitoring Well Development, SOP-101 and Groundwater Sampling Using Micropurge Technology, SOP-103. Respective templates are provided as attachments to both SOP-101 and SOP-103. At a minimum, the following basic information should be recorded on the forms:

- Project name and site
- Well identification number
- Date and time of sampling or development
- Water level and reference elevation
- Volume of water to be purged
- Pertinent well construction information (total depth, well diameter, etc.)
- Measurement of field parameters such as pH, turbidity, conductivity, and temperature, as well as the times at which the readings were taken.
- Type of purging and sampling equipment used
- Type of samples collected
- Sampler's initials

2.5 DOCUMENTATION OF SAMPLING ACTIVITIES

Documentation to be made during sampling activities includes sample labels, sample seals, chain-of-custody (COC) records, and airbill and identification of courier. The FTL is responsible for submitting the COC record to the data manager for input into the project database. This topic is further discussed in SOP-4, Sample Management and Shipping.

2.5.1 Sample Labels

A sample label, written in indelible ink, should be affixed to all sample containers. The following information should be included at a minimum:

- Sample number
- Type of sample (grab or composite)
- Type of preservative, if applicable
- Date and time of collection
- Project location
- Analytical method
- Initials of sampling personnel

2.5.2 Custody Seals

Custody seals consist of security tape with the initials of the sampler and the date placed over the lid of each cooler containing samples. The tape should be placed such that the seal must be broken to gain access to the contents. Custody seals should not be placed directly onto the volatile organic compound (VOC) sample bottles. Custody seals should be placed on coolers prior to the sampling team's release to a second or third party (e.g., shipment to the laboratory).

2.5.3 Chain-of-Custody Records

COC procedures allow for the tracing of possession and handling of individual samples from the time of field collection through laboratory analysis. The COC is documented through a record that lists each sample and the individuals responsible for sample collection, shipment, and receipt. A sample is considered in custody if it is any of the following:

- In a person's possession.
- In view after being in physical possession.
- Locked or sealed so that no one can tamper with it after it has been in an individual's physical custody.
- In a secured area, restricted to authorized personnel.

A COC record is used to record the samples taken and the analyses requested. It is the legal record for maintaining accountability of control over the sample. Information recorded includes:

- Time and date of sample collection
- Sample identification number and the matrix of the sample

- Sampler's signature
- Required analysis
- Number and type of containers and preservatives

A copy of the COC record should be retained by the sampler prior to release to a second or third party.

Shipping receipts should be signed and filed as evidence of custody transfer between field sampler(s), courier, and laboratory. The COC record will be properly signed and the date of collection and shipment recorded, along with the sample site identifications and requested analyses for each sample.

DISCLAIMER
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1.0 INTRODUCTION

In any sampling program, the integrity of a sample must be ensured from its point of collection to its final disposition. Procedures for classifying, packaging, and shipping samples are described below. Steps in the procedures should be followed to ensure sample integrity and to protect the welfare of persons involved in shipping and receiving samples. When hazardous substances and dangerous goods are sent by common carrier, their packaging, labeling, and shipping are regulated by the U.S. Department of Transportation (DOT) Hazardous Materials Regulations (HMR, Code of Federal Regulations, Title 49 [49 CFR] Parts 106 through 180) and the International Air Transportation Association (IATA) Dangerous Goods Regulations (DGR).

1.1 PURPOSE

This Standard Operating Procedure (SOP) establishes the requirements and procedures for packaging and shipping samples. It has been prepared in accordance with the U.S. Environmental Protection Agency (EPA) "Sampler's Guide to the Contract Laboratory Program (CLP)," the DGR, and the HMR. Sample packaging and shipping procedures described in this SOP should be followed for all sample packaging and shipping. Deviations from the procedures in this SOP must be documented in a field logbook.

1.2 SCOPE

This SOP applies to sample management, packaging, and shipping.

1.3 DEFINITIONS

Custody seal: A custody seal is a tape-like seal. Placement of the custody seal is part of the chain-of-custody process and is used to prevent tampering with samples after they have been packaged for shipping.

Dangerous goods: Dangerous goods are articles or substances that can pose a significant risk to health, safety, or property when transported by air; they are classified as defined in Section 3 of the DGR (IATA 1999).

Environmental samples: Environmental samples include drinking water, groundwater and ambient surface water, soil, sediment, treated municipal and industrial wastewater effluent, and biological specimens.

Hazardous Materials Regulations: The HMR are DOT regulations for the shipment of hazardous materials by air, water, and land; they are located in 49 CFR 106 through 180.

Hazardous samples: Hazardous samples include dangerous goods and hazardous substances. Hazardous samples shipped by air should be packaged and labeled in accordance with procedures specified by the DGR; ground shipments should be packaged and labeled in accordance with the HMR.

Hazardous substance: A hazardous substance is any material, including its mixtures and solutions, that is listed in Appendix A of 49 CFR 172.101 and its quantity, in one package, equals or exceeds the reportable quantity (RQ), listed in the appendix.

IATA Dangerous Goods Regulations: The DGR are regulations that govern the international transport of dangerous goods by air. The DGR are based on the International Civil Aviation

Organization (ICAO) Technical Instructions. The DGR contain all of the requirements of the ICAO Technical Instructions and are more restrictive in some instances.

Nonhazardous samples: Nonhazardous samples are those samples that do not meet the definition of a hazardous sample and do not need to be packaged and shipped in accordance with the DGR or HMR.

Overpack: An enclosure used by a single shipper to contain one or more packages and to form one handling unit (IATA 1999). For example, a cardboard box may be used to contain three fiberboard boxes to make handling easier and to save on shipping costs.

1.4 REFERENCES

Code of Federal Regulation available on-line at http://www.gpoaccess.gov/cfr/index.html

International Air Transport Association (IATA). 2007. "Dangerous Goods Regulations." 48th Edition.

U.S. Environmental Protection Agency (EPA). 1996. "Sampler's Guide to the Contract Laboratory Program." Office of Solid Waste and Emergency Response. Washington, DC. EPA/540/R-96/032. On-Line Address: Http://www.epa.gov/oerrpage/superfund/programs/clp/guidance.htm#sample

EPA. 1992. Specifications and Guidance for Obtaining Contaminant-Free Sample Containers. April.

2.0 PROCEDURES

The following procedures apply to packaging and shipping nonhazardous and hazardous samples.

2.1 SAMPLE CONTAINERS

All samples will be placed in contaminant-free containers as specified in the EPA's Specification and Guidance for Obtaining Contaminant-Free Sample Containers (EPA 1992). Containers will be stored in cool, dry, clean areas to prevent exposure to fuels, solvents, and other non-site related impacts. Sample containers with preservatives added by the laboratory will not be used if held for an extended period on the job site or exposed to extreme heat conditions.

The sample containers to be used will be dependent on the sample matrix and analyses desired. Unless specified otherwise by the project-specific sampling and analysis plan, the containers to be used for various analyses are described in the Generic Site-wide Sampling and Analysis plan, Table 5a. Sample containers will be filled with minimal headspace, except containers for volatile organic compound (VOC) analyses, which will be filled completely with no headspace. The no-headspace requirement applies to both soil and groundwater samples. Once opened, the containers will be used immediately. If the container is used for any reason in the field (e.g., screening) and not sent to the laboratory for analysis, it will be discarded. Prior to discarding the contents of the used container and/or the container, disposal requirements will be evaluated to assess whether the contents or the container require disposal as a hazardous material. Some sample types require specific handling procedures, including:

- Compressed gas cylinders
- Radioactive substances
- Biological hazards

If any of these materials are associated with a project, the field personnel must follow the heath and safety procedures defined in the project-specific plans.

2.2 FIELD SAMPLE IDENTIFICATION AND LABELING

Field Sample Identification.
Protocol for field sample identification will be clearly defined in the project-specific sampling and analysis plans.

Sample Label.
A sample label will be affixed to all sample containers. The sample label, at a minimum will be completed with the following information:

- Client name
- Sample identification number
- Date and time of sample collection
- Type of sample (grab or composite)
- Initials of sampler
- Preservative used
- Analyte(s)

If a sample is split with another party, identical labels will be attached to each sample container. After labeling, each sample will be refrigerated or placed upright in a cooler. Wet ice in double Resealable (e.g. Ziploc®) bags (to prevent leakage) will be placed around, among, and on top of the sample bottles. Enough ice will be used so that the samples will be chilled and maintained at 4 degrees Celsius (°C) + 2 °C prior to and during transport to the laboratory.

2.3 CHAIN-OF-CUSTODY (COC)

COC procedures require a written record of the possession of individual samples from the time of collection through laboratory analyses. A sample is considered to be in custody if it is:

- In a person's possession
- In view after being in physical possession

- In a secured condition after having been in physical custody
- In a designated secure area, restricted to authorized personnel

The COC record will be used to document the samples collected and the required analyses. Information recorded by field personnel on the COC record will include the following (see attached):

- Client name
- Project name
- Project location
- Sampling location
- Signature of sampler(s)
- Sample identification number
- Date and time of collection
- Sample designation (grab or composite)
- Sample matrix
- Signature of individuals involved in custody transfer (including date and time of transfer)
- Airbill number (if appropriate)
- Number and type of bottles collected for each analysis
- Type of analysis and laboratory method number
- Any comments regarding individual samples (e.g., organic vapor meter readings, special instructions).

All COC entries will be made using indelible ink and will be legible. Any errors will be corrected by drawing a single line through the incorrect entry, entering the correct information, and then initialing and dating the change. Unused portions of the COC form will be crossed out with a single strike through and initialed and dated by the field sampler. If the samples are transferred directly from the field sampler to the laboratory, both the receiving and relinquishing individuals will sign the COC. If samples are transported to the laboratory by a commercial carrier, signed airbills or other applicable bills of lading will serve as evidence of custody transfer between the field sampler and carrier as well as carrier and laboratory. The sampler will retain copies of the COC record and airbills, or bills of lading. If the COC records are sequentially numbered the record number and airbill number will be cross-referenced in the field logbook or appropriate field form.

2.4 SAMPLE TRACKING

The sample register maybe electronic or a bound logbook with sequentially numbered pages. The sample register is used to document which samples were collected each day. The sample register is also used as the key to correlate field samples with duplicate samples. Information that will be recorded in the sample register includes the following:

- Client name
- Project name and location
- Job number
- Date and time of collection
- Sample identification number
- Sample designation (e.g., grab or composite, etc.)
- Sample matrix (e.g., soil, groundwater, etc.)
- Number and type of bottles
- Type of analysis
- Sample destination
- Sampler's initials

If the sample register is electronic, a hard copy of each day's sampling activities will be maintained in the field logbook. Refer to SOP-3 Field Documentation for specific details regarding documentation procedures.

2.5 SAMPLE PRESERVATION/STORAGE

The requirements for sample preservation are dependent on the desired analyses and the sample matrix. Unless otherwise specified by the project plan, sample preservation requirements outlined in the Generic Site-wide Sampling and Analysis plan will be observed.

2.6 QUALITY CONTROL SAMPLE MANAGEMENT

The number and types of quality control (QC) samples to be collected for a project will be defined in the Generic Site-wide Sampling and Analysis plan.

2.7 SAMPLE HOLDING TIMES

The holding times for samples will depend on the analysis and the sample matrix. Unless otherwise specified, holding times listed in the Generic Site-wide Sampling and Analysis plan will be followed.

3.0 SAMPLE CLASSIFICATION AND SHIPPING

Most environmental samples are not hazardous samples and do not need to be packaged or shipped in accordance with DGR or HMR regulations. Prior to sample shipment, it must be determined whether the sample is subject to the DGR and/or HMR. It is the responsibility of the field team leader to determine if any samples are subject to the DGR and the HMR, and to ensure that these materials are shipped properly. Samples subject to these regulations shall be referred to as hazardous samples and must be shipped in proper containers with appropriate labeling and shipping papers.

If the hazardous sample is to be shipped by air, then the DGR must be followed. Any airline, including FedEx, belonging to IATA must follow the DGR. As a result, FedEx may not accept a shipment that is packaged and labeled in accordance with the HMR (although in most cases, the packaging and labeling would be the same for either set of regulations). The HMR states that a hazardous material may be transported by aircraft in accordance with the ICAO Technical Instruction (49 CFR 171.11) upon which the DGR is based. Therefore, the use of the DGR for samples to be shipped by air complies with the HMR, but not vice versa.

Hazardous samples are those samples that can be classified as specified in Section 3 of the DGR, can be found in the List of Dangerous Goods in the DGR in bold type, are considered a hazardous substance (see definition), or are mentioned in "Section 2 - Limitations" of the DGR for countries of transport or airlines (such as FedEx). The hazard classifications specified in the DGR (and the HMR) are as follows:

Class 1 - Explosives

Division 1.1-Articles and substances having a mass explosion hazard

Division 1.2-Articles and substances having a projection hazard but not a mass explosion hazard

Division 1.3-Articles and substances having a fire hazard, a minor blast hazard and/or a minor projection hazard but not a mass explosion hazard

Division 1.4-Articles and substances presenting no significant hazard

Division 1.5-Very insensitive substances which have a mass explosion hazard

Division 1.6-Extremely insensitive articles which do not have a mass explosion hazard

Class 2 - Gases

Division 2.1-Flammable gas

Division 2.2-Non-flammable, non-toxic gas

Division 2.3-Toxic gas

Class 3 - Flammable Liquids

Class 4 - Flammable Solids; Substances Liable to Spontaneous Combustion; Substances, which, in Contact with Water, Emit Flammable Gases

Division 4.1-Flammable solids.

Division 4.2-Substances liable to spontaneous combustion.

Division 4.3-Substances, which, in contact with water, emit flammable gases.

Class 5 - Oxidizing Substances and Organic Peroxide

Division 5.1-Oxidizers.

Division 5.2-Organic peroxides.

Class 6 - Toxic and Infectious Substances

Division 6.1-Toxic substances.

Division 6.2-Infectious substances.

Class 7 - Radioactive Material

Class 8 - Corrosives

Class 9 - Miscellaneous Dangerous Goods

The criteria for each of the first eight classes are very specific and are outlined in Section 3 of the DGR and 49 CFR 173 of the HMR. The following discussion provides very generalized information on certain hazard classes but should not be used in place of the specific DGR and HMR when determining the hazardous class and shipping requirements for a sample.

Some classes and divisions are further divided into packing groups based on their level of danger. Packing group I indicates a great danger, packing group II indicates a medium danger, and packing group III indicates a minor danger. Class 2, gases, includes any compressed gas being shipped and any noncompressed gas that is either flammable or toxic. A compressed gas is defined as having a pressure over 40 pounds per square inch (psi) absolute (25 psi gauge). Most air samples and empty cylinders that did not contain a flammable or toxic gas are exempt from the regulations. An empty hydrogen cylinder, as in a flame ionization detector (FID), is considered a dangerous good unless it is properly purged with nitrogen in accordance with the HMR. A landfill gas sample is usually considered a flammable gas because it may contain a high percentage of methane. Class 3, flammable liquids, is based on the boiling point and flash point of a substance. Most class 3 samples include solvents, oil, gas, or paint-related material collected from drums, tanks, or pits. Division 6.1, toxic substances, is based on oral toxicity (LD50 [lethal dose that kills 50 percent of the test animals]), dermal toxicity (LD50 values), and inhalation toxicity (LC50 [lethal concentration that kills 50 percent of the test animals] values). Division 6.1 substances include pesticides and cyanide. Class 7, radioactive material, is defined as any article or substance with a specific activity greater than 70 kiloBecquerels (kBq/kg) (0.002 [microCuries per gram [μCi/g]). If the specific activity exceeds this level, the sample should be shipped in accordance with Section 10 of the DGR. Class 8, corrosives, are based on the rate at which a substance destroys skin tissue or corrodes steel; they are not based on pH. Class 8 materials include the concentrated acids used to preserve water samples. Preserved water samples are not considered class 8 substances and should be packaged as nonhazardous samples. Class 9, miscellaneous dangerous goods, are substances that present a danger but are not covered by any other hazard class. Examples of Class 9 substances include asbestos, polychlorinated biphenyls (PCB), and dry ice.

Unlike the DGR, the HMR includes combustible liquids in hazard Class 3. The definition of a combustible liquid is specified in 49 CFR 173.120 of the HMR. The HMR has an additional class, ORM-D, that is not specified in the DGR. “ORM-D material” refers to a material such as a consumer commodity, that although otherwise subject to the HMR, presents a limited hazard during transport due to its form, quantity, and packaging. It must be a material for which exceptions are provided in the table of 49 CFR 172.101. The DGR lists consumer commodities as a Class 9 material.

In some instances, the hazard of a material sampled is unknown because no laboratory testing has been conducted. A determination as to the suspected hazard of the sample must be made using knowledge of the site, field observations, field tests, and other available information. According to 40 CFR 261.4(d) and (e), samples transported to a laboratory for testing or treatability studies, including samples of hazardous wastes, are not hazardous wastes. FedEx will not accept a shipment of hazardous waste.

3.1 PACKAGING NONHAZARDOUS SAMPLES

Nonhazardous samples, after being appropriately containerized, labeled, and tagged, should be packaged in the following manner.

1. Place the sample in a resealable plastic bag.

2. Place the bagged sample in a cooler and pack it to prevent breakage.

3. Prevent breakage of bottles during shipment by wrapping the sample container in bubble wrap. It is recommended that the cooler be lined with a large plastic garbage bag before samples, ice, and absorbent packing material are placed in the cooler.

4. Add a sufficient quantity of ice to the cooler to cool and hold samples to 4 °C until arrival at the laboratory. Ice should be double bagged in resealable plastic bags to prevent the melted ice from leaking out. A temperature blank (a sample bottle filled with distilled water) will be included with the cooler.

5. Seal the completed chain-of-custody forms in a plastic bag and tape the plastic bag to the inside of the cooler lid.

6. Tape any instructions for returning the cooler to the inside of the lid.

7. Close the lid of the cooler and tape it shut by wrapping strapping tape around both ends and hinges of the cooler at least once. Tape shut any drain plugs on the cooler.

8. Place two signed custody seals on the cooler, ensuring that each one covers the cooler lid and side of the cooler. Place clear plastic tape over the custody seals.

9. Place address labels on the outside of the cooler.

10. Ship samples overnight by a commercial carrier such as FedEx.

3.2 PACKAGING HAZARDOUS SAMPLES

The procedures for packaging hazardous samples are summarized below. Note that according to the DGR, all spellings must be exactly as they appear in the List of Dangerous Goods, and only approved abbreviations are acceptable. The corresponding HMR regulations are provided in parentheses following any DGR referrals. The HMR must be followed only if shipping hazardous samples by ground transport.

1. Determine the proper shipping name for the material to be shipped. All proper shipping names are listed in column B of the List of Dangerous Goods table in Section 4 of the DGR (or column 2 of the Hazardous Materials Table in 49 CFR 172.101). In most instances, a generic name based on the hazard class of the material is appropriate. For example, a sample of an oily liquid collected from a drum with a high photoionization detector (PID) reading should be packaged as a flammable liquid. The proper shipping name chosen for this sample would be "flammable liquid, n.o.s." The abbreviation "n.o.s." stands for "not otherwise specified" and is used for generic shipping names. Typically, a specific name, such as acetone, should be inserted in parentheses after most n.o.s. descriptions. However, a technical name is not required when shipping a sample for testing purposes and the components are not known. If shipping a hazardous substance (see definition), then the letters "RQ" must appear in front of the proper shipping name.

2. Determine the United Nations (UN) identification number, class or division, subsidiary risk if any, required hazard labels, packing group, and either passenger aircraft or cargo aircraft packing instructions based on the quantity of material being shipped in one package. This information is provided in the List of Dangerous Goods (or Hazardous Materials Table in 49 CFR 172.101) under the appropriate proper shipping name. A "Y" in front of a packing instruction indicates a limited quantity packing instruction. If shipping dry ice or a limited quantity of a material, then UN specification shipping containers may not need to be used.

3. Determine the proper packaging required for shipping the samples. Except for limited quantity shipments and dry ice, these are UN specification packages that have been tested to meet the packing group of the material being shipped. Specific testing requirements of the packages is listed in Section 6 of the DGR (or 49 CFR 178 of the HMR). All UN packages are stamped with the appropriate UN specification marking. Prior planning is required to have the appropriate packages on hand during a sampling event where hazardous samples are anticipated. Most samples can be shipped in either a 4G fiberboard box, a 1A2 steel drum, or a 1H2 plastic drum. Drums can be purchased in 5- and 20-gallon sizes and are ideal for shipping multiple hazardous samples. When FedEx is used to ship samples containing PCBs, the samples must be shipped in an inner metal packaging (paint can) inside a 1A2 outer steel drum. This method of packaging PCB samples is in accordance with FedEx variation FX-06, listed in Section 2 of the DGR.

4. Place each sample jar in a separate resealable plastic bag. Some UN specification packagings contain the sample jar and plastic bag to be used when shipping the sample.

5. Place each sealed bag inside the approved UN specification container (or other appropriate container if a limited quantity or dry ice) and pack with enough noncombustible, absorbent, cushioning material to prevent breakage and to absorb liquid.

6. Place chain-of-custody forms in a resealable plastic bag and either attach it to the inside lid of the container or place it on top inside the container. Place instructions for returning the container to the shipper on the inside lid of the container as appropriate. Close and seal the shipping container in the manner appropriate for the type of container being used.

7. Label and mark each package appropriately. All irrelevant markings and labels need to be removed or obliterated. All outer packagings must be marked with proper shipping name, UN identification number, and name and address of the shipper and the recipient. For carbon dioxide, solid (dry ice), the net weight of the dry ice within the package needs to be marked on the outer package. For limited quantity shipments, the words “limited quantity” or “LTD. QTY.” must be marked on the outer package. Affix the appropriate hazard label to the outer package. If the material being shipped contains a subsidiary hazard, then a subsidiary hazard label must also be affixed to the outer package. The subsidiary hazard label is identical to the primary hazard label except that the class or division number is not present. It is acceptable to obliterate the class or division marking on a primary hazard label and use it as the subsidiary hazard label. If using cargo aircraft only packing instructions, then the “Cargo Aircraft Only” label must be used. Package orientation labels (up arrows) must be placed on opposite sides of the outer package. Figure 1 depicts a properly marked and labeled package.

8. If using an overpack (see definition), mark and label the overpack and each outer packaging within the overpack as described in step 7. In addition, the statement

"INNER PACKAGES COMPLY WITH PRESCRIBED SPECIFICATIONS" must be marked on the overpack.

9. Attach custody seals, and fill out the appropriate shipping papers as described in Section

3.3 SHIPPING PAPERS FOR HAZARDOUS SAMPLES

A "Shippers Declaration for Dangerous Goods" and "Air Waybill" must be completed for each shipment of hazardous samples. FedEx supplies a Dangerous Goods Airbill to its customers; the airbill combines both the declaration and the waybill. An example of a completed Dangerous Goods Airbill is depicted in Figure 2. A shipper's declaration must contain the following:

- Name and address of shipper and recipient
- Air waybill number (not applicable to the HMR)
- Page ___ of ___
- Deletion of either "Passenger and Cargo Aircraft" or "Cargo Aircraft Only," whichever does not apply
- Airport or city of departure
- Airport or city of destination
- Deletion of either "Non-Radioactive" or "Radioactive," which ever does not apply
- The nature and quantity of dangerous goods. This includes the following information in the following order (obtained from the List of Dangerous Goods in the DGR): proper shipping name, class or division number, UN identification number, packing group number, subsidiary risk, quantity in liters or kilograms (kg), type of packaging used, packing instructions, authorizations, and additional handling information. Authorizations include the words "limited quantity" or "LTD. QTY." if shipping a limited quantity, any special provision numbers listed in the List of Dangerous Goods in the DGR, and the variation "USG-14" when a technical name is required after the proper shipping name but not entered because it is unknown.
- Signature for the certification statement
- Name and title of signatory
- Place and date of signing certification

- A 24-hour emergency response telephone number for use in the event of an incident involving the dangerous good

- Emergency response information attached to the shipper's declaration. This information can be in the form of a material safety data sheet or the applicable North American Emergency Response Guidebook (NAERG; DOT 1996) pages. Figure 3 depicts the appropriate NAERG emergency response information for "Flammable liquids, n.o.s." as an example.

Note that dry ice does not require an attached shipper's declaration. However, the air waybill must include the following on it: "Dry ice, 9, UN1845, ____ x ____ kg." The blanks must include the number of packages and the quantity in kg in each package. If using FedEx to ship dry ice, the air waybill includes a box specifically for dry ice. Simply check the appropriate box and enter in the number of packages and quantity in each package.

The HMR requirements for shipping papers are located in 49 CFR 172 Subpart C.

4.0 POTENTIAL PROBLEMS

The following potential problems may occur during sample shipment:

- Leaking package. If a package leaks, the carrier may open the package, return the package, and if a dangerous good, inform the Federal Aviation Administration (FAA), which can result in fines.

- Improper labeling and marking of package. Improper labeling, marking and shipping of hazardous materials is a violation of federal regulations that can result in enforcement and significant fines.

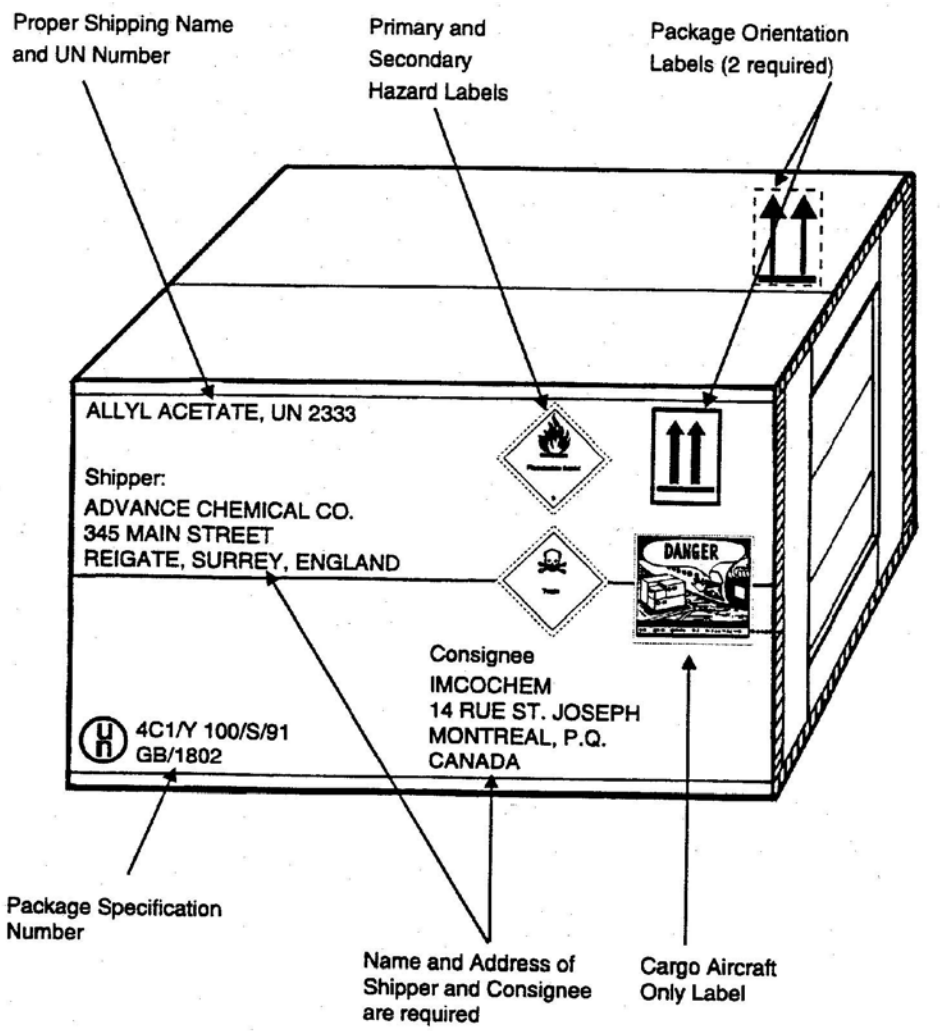
- Improper, misspelled, or missing information on the shipper's declaration. Improper completion of the shippers declaration is a violation of federal regulations that can result in enforcement and significant fines.

Contact FedEx with any questions about dangerous goods shipments by calling 1-800-463-3339 and asking for a dangerous goods expert.

DISCLAIMER
This SOP provided general guidance for TIMET contractors and subcontractors for technical issues addressed during environmental site investigation and remediation activities. It is noted, however, that each site and project is unique and these guidelines are not a substitute for common sense and good management practices based on professional training and experience. In addition, individual contract terms may affect the implementation of this SOP. TIMET contractors reserve the unrestricted right to change, modify or not apply these guidelines in their sole, complete, and unrestricted discretion to meet certain circumstances, contractual requirements, site conditions, or job requirements.

FIGURE 1

EXAMPLE OF A CORRECTLY MARKED AND LABELED DANGEROUS GOODS PACKAGE



Source: International Air Transport Association (IATA). 1997.

FIGURE 2
EXAMPLE OF A DANGEROUS GOODS AIRBILL

FedEx Dangerous Goods Airbill — Sender's Copy — RETAIN THIS COPY FOR YOUR RECORDS

11729489

1 From Please print and press hard.

Date: FILL IN — Sender's FedEx Account Number: 1788-8014-4

Sender's Name: FILL IN — Phone (312) 856 8700

Company: TETRA TECH EM INC

Address: 200 E RANDOLPH ST STE 4700 — Dept./Floor/Suite/Room

City: CHICAGO — State: IL — ZIP: 60601

2 Your Internal Billing Reference (First 24 characters will appear on invoice.): FILL IN

3 To

Recipient's Name: FILL IN — Phone ( )

Company:

Address: (To "HOLD" at FedEx location, print FedEx address here) We cannot deliver to P.O. boxes or P.O. ZIP codes. — Dept./Floor/Suite/Room

City: — State: — ZIP:

For HOLD at FedEx Location check here: ☐ Hold Weekday ☐ Hold Saturday (Available for FedEx Priority Overnight and FedEx 2Day to select locations)

For WEEKEND Delivery check here: ☐ Saturday Delivery (Available for FedEx Priority Overnight and FedEx 2Day to select ZIP codes) ☐ Sunday Delivery (Available for FedEx Priority Overnight to select ZIP codes)

4a Express Package Service Packages up to 150 lbs. — Delivery commitment may be later in some areas.
☒ FedEx Priority Overnight (Next business morning) ☐ FedEx Standard Overnight (Next business afternoon)
☐ FedEx 2Day (Second business day) ☐ FedEx Express Saver (Third business day)

4b Express Freight Service Packages over 150 lbs. — Delivery commitment may be later in some areas.
☐ FedEx 1Day Freight* (Next business day) ☐ FedEx 2Day Freight (Second business day) ☐ FedEx 3Day Freight (Third business day)
* Call for Confirmation:

The World On Time.

See the FedEx Service Guide for further details

Questions? Call 1•800•Go•FedEx® (800-463-3339) or Visit our Web site at www.fedex.com

5 Packaging ☒ Other Packaging — Dangerous Goods cannot be shipped in FedEx packaging.

6 Special Handling ☒ Dangerous Goods as per attached Shipper's Declaration ☐ Cargo Aircraft Only

7 Payment Bill to: ☒ Sender (Acct. No. in Section 1 will be billed) ☐ Recipient ☐ Third Party ☐ Credit Card ☐ Cash/Check (Enter FedEx Acct. No. or Credit Card No. below)

FedEx Account No.:

Credit Card No.: — Exp. Date:

Total Packages — Total Weight — Total Declared Value* $ .00 — FedEx Use Only

* When declaring a value higher than $100 per shipment, you pay an additional charge. See SERVICE CONDITIONS, DECLARED VALUE, AND LIMIT OF LIABILITY section for further information.

Signature Release Unavailable

PART #154827 • Rev. Date 11/98 ©1994-98 FedEx • PRINTED IN U.S.A.

374 — WCSL 6/99

FedEx Tracking Number: 813350883058 — Form I.D. No.: 0204

Page 1 of 1 Pages

Two completed and signed copies of this Declaration must be handed to the operator.

WARNING

Failure to comply in all respects with the applicable Dangerous Goods Regulations may be in breach of the applicable law, subject to legal penalties. This Declaration must not, in any circumstances, be completed and/or signed by a consolidator, a forwarder or an IATA cargo agent.

TRANSPORT DETAILS

This shipment is within the limitations prescribed for: (delete non-applicable) PASSENGER AND CARGO AIRCRAFT / ~~CARGO AIRCRAFT ONLY~~

Airport of Departure: Chicago

Airport of Destination: "City sending sample to"

Shipment type: (delete non-applicable) NON-RADIOACTIVE / ~~RADIOACTIVE~~

NATURE AND QUANTITY OF DANGEROUS GOODS

Proper Shipping Name	Class or Division	UN or I.D. No.	Packing Group	Subsidiary Risk	Quantity and Type of Packaging	Packing Instr.	Authorization
Flammable liquid, n.o.s.	3	UN 1993	III	—	4 glass jars in a 1A2 steel drum Net Quantity = 4 L	309	A3 USG-14

Additional Handling Information: NAERG # 128 Attached.

Prepared for AIR TRANSPORT according to: (Customer MUST check one) ☐ 49 CFR ☒ ICAO / IATA

I hereby declare that the contents of this consignment are fully and accurately described above by the proper shipping name and are classified, packaged, marked, and labeled/placarded, and are in all respects in proper condition for transport according to applicable international and national governmental regulations.

Name/Title of Signatory: Me, Environmental Scientist

Place and Date: 200 E Randolph, Chicago, IL xx/xx/xx

Signature (see warning above): me

Emergency Telephone Number (Required for U.S. Origin or Destination Shipments): FILL IN

IF ACCEPTABLE FOR PASSENGER AIRCRAFT, THIS SHIPMENT CONTAINS RADIOACTIVE MATERIAL INTENDED FOR USE IN, OR INCIDENT TO, RESEARCH, MEDICAL DIAGNOSIS, OR TREATMENT.

FIGURE 3
NAERG EMERGENCY RESPONSE INFORMATION FOR FLAMMABLE LIQUIDS, N.O.S.

GUIDE 128 FLAMMABLE LIQUIDS (NON-POLAR/WATER-IMMISCIBLE) NAERG96

POTENTIAL HAZARDS

FIRE OR EXPLOSION

- **HIGHLY FLAMMABLE: Will be easily ignited by heat, sparks or flames.**
- Vapors may form explosive mixtures with air.
- Vapors may travel to source of ignition and flash back.
- Most vapors are heavier than air. They will spread along ground and collect in low or confined areas (sewers, basements, tanks).
- Vapor explosion hazard indoors, outdoors or in sewers.
- Some may polymerize (P) explosively when heated or involved in a fire.
- Runoff to sewer may create fire or explosion hazard.
- Containers may explode when heated.
- Many liquids are lighter than water.
- Substance may be transported hot.

HEALTH

- Inhalation or contact with material may irritate or burn skin and eyes.
- Fire may produce irritating, corrosive and/or toxic gases.
- Vapors may cause dizziness or suffocation.
- Runoff from fire control or dilution water may cause pollution.

PUBLIC SAFETY

- **CALL Emergency Response Telephone Number on Shipping Paper first. If Shipping Paper not available or no answer, refer to appropriate telephone number listed on the inside back cover.**
- Isolate spill or leak area immediately for at least 25 to 50 meters (80 to 160 feet) in all directions.
- Keep unauthorized personnel away.
- Stay upwind.
- Keep out of low areas.
- Ventilate closed spaces before entering.

PROTECTIVE CLOTHING

- Wear positive pressure self-contained breathing apparatus (SCBA).
- Structural firefighters' protective clothing will only provide limited protection.

EVACUATION

Large Spill

- Consider initial downwind evacuation for at least 300 meters (1000 feet).

Fire

- If tank, rail car or tank truck is involved in a fire, ISOLATE for 800 meters (1/2 mile) in all directions; also, consider initial evacuation for 800 meters (1/2 mile) in all directions.

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NAERG96 FLAMMABLE LIQUIDS (NON-POLAR/WATER-IMMISCIBLE) **GUIDE 128**

EMERGENCY RESPONSE

FIRE

CAUTION: All these products have a very low flash point: Use of water spray when fighting fire may be inefficient.

Small Fires

- Dry chemical, CO_2, water spray or regular foam.

Large Fires

- Water spray, fog or regular foam.
- Do not use straight streams.
- Move containers from fire area if you can do it without risk.

Fire involving Tanks or Car/Trailer Loads

- Fight fire from maximum distance or use unmanned hose holders or monitor nozzles.
- Cool containers with flooding quantities of water until well after fire is out.
- Withdraw immediately in case of rising sound from venting safety devices or discoloration of tank.
- ALWAYS stay away from the ends of tanks.
- For massive fire, use unmanned hose holders or monitor nozzles; if this is impossible, withdraw from area and let fire burn.

SPILL OR LEAK

- ELIMINATE all ignition sources (no smoking, flares, sparks or flames in immediate area).
- All equipment used when handling the product must be grounded.
- Do not touch or walk through spilled material.
- Stop leak if you can do it without risk.
- Prevent entry into waterways, sewers, basements or confined areas.
- A vapor suppressing foam may be used to reduce vapors.
- Absorb or cover with dry earth, sand or other non-combustible material and transfer to containers.
- Use clean non-sparking tools to collect absorbed material.

Large Spills

- Dike far ahead of liquid spill for later disposal.
- Water spray may reduce vapor; but may not prevent ignition in closed spaces.

FIRST AID

- Move victim to fresh air.
- Call emergency medical care.
- Apply artificial respiration if victim is not breathing.
- Administer oxygen if breathing is difficult.
- Remove and isolate contaminated clothing and shoes.
- In case of contact with substance, immediately flush skin or eyes with running water for at least 20 minutes.
- Wash skin with soap and water.
- Keep victim warm and quiet.
- Ensure that medical personnel are aware of the material(s) involved, and take precautions to protect themselves.

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Source: DOT and others. 1996.

Paragon Analytics
A Division of DataChem Laboratories, Inc.
225 Commerce Drive Fort Collins, CO 80524
800-443-1511 or (970) 490-1511 (970) 490-1522 Fax

Accession Number (LAB ID) ________________

Chain-of-Custody

Date ____________ Page ___ of ____ **Originator**: **Retain pink copy**

Project Name / No.: ____________________ **Sampler(s):** _________________ Turnaround (circle one): **Standard** or **Rush (Due** ____________ **)** Dispose: **Date** __________ or **Return** to Client

Report To:
Phone:
Fax:
E-mail:
Company:
Address:

Circle method (right); provide additional information as needed (comments).

Sample ID	Date	Time *	Lab ID	Matrix	Preservative (indicate type)	No. of Containers	VOCs SW8260B E624 E524.2	BTEX (only) SW8021B	SVOCs SW8270C E625	OC Pesticides SW8081A E608	PCBs SW8082 E608	Herbicides SW8151A	Explosives SW8330	TCLP Organics SW1311 SW8260B 8270C 8081A 8151A	TCLP Metals SW1311 SW6010B SW7471	Total Metals by ICP SW6010B 7470 7471 E200 ILMO__	Dissolved Metals by ICP SW6010B 7470 E200 ILMO__	Total Metals by ICP/MS SW6020 E200.8 ILMO__	Dissolved Metals by ICP/MS SW6020 E200.8 ILMO__	Hexavalent Chromium SW7196A Alkaline Digest? Y / N	Inorganic Anions SW9056 E300.0 (specify in comments)	Solids: Total E160.3 TDS E160.1 TSS E160.2	pH SW9040B SW9045C	TPH GRO DRO SW8015B (both)	Gross Alpha / Beta SW9310 E900.0	Actinides by Paragon SOP Pu / U / Am / Th / Cm / ___	Tritium E906.0	Total Alpha-Emitting Radium SW9315 E903.0	Radium 226 E903.1 Radium 228 SW9320 E904.0	Strontium 89 D5811-00 Strontium 90 D5811-00	Gamma Isotopes E901.1					

*** Time Zone:** EST CST MST PST **Matrix Key:** O = oil, S = soil, NS = non-soil solid, W = water, L = liquid, E = extract, F = filter

Comments:

Relinquished By: **(1)**	*Relinquished By:* **(2)**
Signature ________________	Signature ________________
Printed Name ________________	Printed Name ________________
Date __________ Time __________	Date __________ Time __________
Company ________________	Company ________________
Received By: **(1)**	*Received By:* **(2)**
Signature ________________	Signature ________________
Printed Name ________________	Printed Name ________________
Date __________ Time __________	Date __________ Time __________
Company ________________	Company ________________

Form 202r5.xls (4/6/04)

1.0 INTRODUCTION

The term investigative derived waste (IDW) typically includes drilling cuttings, drilling muds, purged well water, decontamination fluids, sample residues, decontamination fluids, personal protective equipment (PPE), and other disposable equipment that is generated from sampling and investigation activities.

Generally, the management of IDW must meet the following criteria:

- It must be protective of human health and the environment.

- It must comply with the applicable or relevant and appropriate requirements (ARARs) unless the ARAR is waived by the applicable regulatory authority. Potential ARARs for IDW include regulations under the Resource Conservation and Recovery Act (RCRA), which include the underground injection control regulations and the Land Disposal Restrictions (LDR); the Clean Water Act; the Clean Air Act; the Toxic Substances Control Act (TSCA); and applicable State environmental laws (NRS 445A.300 to 445A.730 and NRS 459.400 to 459.600). To the extent that the U.S. Environmental Protection Agency (EPA) has issued regulations relating to cleanup standards for specific chemicals, those standards must normally be followed unless either a waiver has been obtained or different site-specific cleanup standards have been established by the appropriate regulatory authority.

1.1 PURPOSE

This Standard Operating Procedure (SOP) is intended to assist the field staff in determining the appropriate manner in which to handle investigation-derived wastes (IDW).

1.2 SCOPE

Although this document is intended to provide a general overview of appropriate IDW management practices, it is the Project Manager's responsibility to ensure that all IDW is properly managed in accordance with applicable federal, state, and local law, the contract requirements, and good professional judgment.

2.0 IDW MANAGEMENT CONSIDERATIONS

In establishing the site-specific plans for handling and managing the IDW, the Project Manager is expected to apply good professional judgment within the context of the applicable ARARs, the contract requirements, the protection of human health and the environment, and the exercise of cost efficiency within the context of good health and safety practices. In selecting the appropriate management option, the Project Manager should consider the following:

- The nature of the contaminants, concentrations, and total volume of IDW

- The media potentially impacted by the various management options

- The location and type of receptors likely to be impacted
- The potential exposure to site workers
- The potential for negative environmental impacts
- The potential for minimizing the volume and toxicity of the IDW
- The potential for mitigating potential harmful effects

3.0 DISPOSAL ALTERNATIVES

The following are general guidelines for the disposal for IDW, based on a review of existing EPA guidance documents. They may be superseded by applicable state or local laws or other ARARs.

- Soils—Drill cuttings and similar contaminated soils should be placed in an appropriate container and prepared for disposal at an appropriate disposal facility. Return of soil cuttings are prohibited by Nevada law. Note for soil cuttings, the container label (typically on drums) will identify the owner as the generator as opposed to the drilling company.
- Hazardous water or other aqueous liquid—Hazardous water or other aqueous liquids should normally be drummed and disposed of at a treatment storage or disposal facility, as appropriate.
- Decontamination Fluids—Decontamination fluids should be drummed and disposed of at an appropriate disposal facility.
- Non-hazardous water— Non-hazardous water should be drummed and disposed of at an appropriate disposal facility.
- PPE and Disposable Equipment—Disposable PPE and equipment that has been decontaminated may be double-bagged and placed in appropriate solid waste containers.
- Materials Pending Analysis—Materials that are being held pending chemical analysis should be properly containerized and marked as potentially hazardous, pending analysis.
- Such materials reasonably believed to be hazardous should be treated as if they were hazardous pending analytical confirmation.

4.0 FIELD COMPLIANCE WITH REQUIREMENTS

Compliance with the applicable legal requirements can generally be achieved by complying with the following general principals:

- Identify the contaminants. The analysis can be based on reasonably available information and the application of reasonable professional judgment. Generally, actual testing is not required.

- Minimize the volume of the IDW. To the extent feasible, IDW containing hazardous substances or wastes should be carefully segregated from other non-hazardous IDW in order to minimize the volume of IDW that must be disposed of as hazardous waste.

- Determine the ARARs. Pay particular attention to RCRA, TSCA and applicable state requirements. Remember that individual State requirements may be more stringent than the corresponding federal requirements. Waivers should be sought when justified.

- Properly containerize potentially contaminated used PPE, disposable equipment, decontamination fluids, and groundwater for disposal.

- Comply with applicable containerization, labeling, and storage and record-keeping requirements.

DISCLAIMER
This SOP provided general guidance for TIMET contractors and subcontractors for technical issues addressed during environmental site investigation and remediation activities. It is noted, however, that each site and project is unique and these guidelines are not a substitute for common sense and good management practices based on professional training and experience. In addition, individual contract terms may affect the implementation of this SOP. TIMET contractors reserve the unrestricted right to change, modify or not apply these guidelines in their sole, complete, and unrestricted discretion to meet certain circumstances, contractual requirements, site conditions, or job requirements.

1.0 INTRODUCTION

This Standard Operating Procedure (SOP) provides basic information on calibration procedures for equipment that is generally used during environmental investigations. Use of field monitoring equipment provides data for on-site, real-time measurements, evaluation of existing conditions, refinement of sampling locations, and health and safety evaluations.

1.1 PURPOSE

This SOP provides a general description of the calibration and operating procedures defined in the manufacturer's instruction manual, which accompanies each piece of equipment. This SOP should be used as a general reference and the manufacturer's instruction manual should be followed at all times by field team members.

1.2 SCOPE

This SOP describes the type of monitoring equipment and provides general requirements for calibrating field equipment. Primary activities are covered below. It should be noted that additional field equipment may be utilized during a field event. The operating and calibration procedures for this equipment will be included in the project-specific sampling and analysis plan.

2.0 MONITORING EQUIPMENT

The Project Manager or Field Team Leader (FLT) is responsible for identifying the appropriate equipment necessary to adequately define the parameters. The Health and Safety Officer will work with the Project Manager in identifying the appropriate safety equipment. The Health and Safety Officer will also perform audits to observe field personnel using the equipment. The FTL will ensure on a daily basis that all field team members properly use the equipment through the duration of the project.

All field monitoring equipment must be calibrated within the last 12 months by a facility certifying that the instruments were calibrated under standards traceable to the National Institute of Standards and Technology and using a calibration system that conforms to the requirements of American National Standards Institute. Calibration documentation will be maintained at the project field office.

2.1 WATER LEVEL METERS

Water level meters are electric contact gages is used for measuring the depth of water in wells, boreholes, or standpipes. Water level meters use a probe, attached to a permanently marked polyethylene tape, fitted on a well-balanced reel. There are conductors embedded within the tape. The probe incorporates an insulating gap between electrodes. When contact is made with water, the circuit is completed, sending a signal back to the reel. This activates a loud buzzer and a light.

2.1.1 Operation

Upon receipt of meter, set the switch to "on" position. To check the circuit, submerse the electrode (probe) in tap water. This completes the circuit and activates the buzzer. Depress the test button to test the battery and circuitry. The zero measurement on most meters is at the tip of the inner electrode, visible near the center of the probe.

2.1.2 Maintenance

After the depth of water has been recorded, the cable should be carefully rewound onto the reel, the probe wiped dry, and replaced into the probe holder. Decontaminate the probe, cable, and reel between each use. To replace the battery, remove the face plate on the reel by unscrewing the three faceplate screws and carefully lifting off to the side to avoid damaging the wiring. Replace the 9-V battery making sure the polarity is correct. Replace the faceplate.

2.2 INTERFACE METER

Interface meters measure the thickness of floating or sinking products in monitoring wells or storage tanks. To detect liquids, interface meters typically use an infra-red beam and detector. When the probe enters a liquid the beam is refracted away from the detector, which activates an audible tone and light. If the liquid is a non-conductive oil/product, the signals are steady. If the liquid is water, the conductivity of the water completes a conductivity circuit. This overrides the infra-red circuit, and the tone and light are intermittent.

2.2.1 Operation

Turn main switch to the "on" position. Also twist probe to the "on" position. A flashing light on the faceplate indicates that the probe is in the "on" position, but the main switch is not "on." A continuous buzz indicates that the main switch is "on", but the probe is "off." Lower probe slowly until lights and audible tone are on. Raise and lower the probe gently to determine the exact upper level of the nonconductive floating product. Note level from marked tape. If no floating product exists, one single light will come on. Continue to lower the probe until only one light is on. Shake the probe slightly at this point to clear any residual product from the conductivity sensor. Raise the probe slowly until both lights and the audible tone are on to determine the product/water interface. Read level directly from the tape. Repeat steps 2 and 3 to confirm readings.

2.2.2 Maintenance

Perform routine calibration prior to each use and at the end of each day. Factory calibrate yearly, when malfunctioning, when the span setting exceeds the maximum span setting for the probe in use, and after the UV light source has been replaced. Clean the main readout assembly after each use. Thoroughly decontaminate the instrument at the completion of the project. Recharge the battery daily. Care should be taken when sampling over solids and liquids so that it is not drawn into the instrument.

2.3 MULTI-PARAMETER WATER QUALITY METERS

There are numerous multi-parameter meters available. Any meter used to collect field measurements should be equipped with probes to measure pH, dissolved oxygen (DO), conductivity, temperature, turbidity, and oxidation-reduction potential (REDOX). These measurements should be recorded in the following units:

- Standard pH units
- DO—milligrams per liter (mg/L)
- Conductivity—milliSiemans per meter (mS/m)
- Temperature—degrees centigrade (°C)
- Turbidity—Nephelometric Turbidity Units (NTUs)
- REDOX—millivolts (mV)

A relative accuracy of ±0.1 pH, ±0.2 mg/L, ±3% mS/m, ±1°C, ±5% NTU, and ±15 mV is adequate for the type of measurement being performed.

2.3.1 Calibration

Always calibrate the instrument according to the manufacturer's instructions, taking into account the guidelines provided in this section. The meter must be calibrated before the start of each workday and checked periodically throughout the workday. The instrument can be generally calibrated with one solution (auto calibration) or can be calibrated by a span calibration, which will give more accurate readings. Consult the instruction manual for further details.

2.3.2 Operation

The main use of this instrument is in a flow-through cell, which will take a reading as water is being continuously pumped through using the low flow or purging methods. The reading can be taken at any time while water is moving through the flow-through cell. Be aware that the meter is not waterproof, but the probe is waterproof.

2.3.3 Maintenance

Clean and decontaminate the instrument after each well. Use a solution of soapy water. Rinse the instrument with clean water. Do not clean the instrument while it is disassembled. Rinse the probe several times with distilled or deionized water. See the manual for instructions on replacing batteries either in the probe or in the LCD readout meter.

2.4. CARBON MONOXIDE, COMBUSTIBLE GAS AND OXYGEN INDICATOR

Ambient air monitoring at hazardous waste sites is a common safety practice. Activity at a site may cause disturbances that release hazardous vapors into the ambient air. These releases can be detected by commercially available portable air monitoring devices that register real-time data. This data can be used to establish the existence of hazards such as oxygen deficient or explosive atmospheres. Personnel protective levels may be based on these readings. It is important that every work area be evaluated by someone trained in hazard control to make sure that the correct instrument is chosen and to determine whether other instruments are necessary to assess the hazard. Evacuate all personnel from the area if the instrument alarm indicates the possibility of a hazardous condition.

2.4.1 Calibration

Prior to each day's usage, sensitivity must be tested on a known concentration of each of the gases for which the instrument is calibrated. The indication must be equal to or higher than the actual concentration. Calibration should be checked and adjusted in fresh air at the elevation where the instrument is to be used. Refer to the manual for more calibration information.

2.4.2 Operation

The combustible gas sensor is designed to measure combustible gas or vapor content in air. It will not indicate the combustible gas content in an inert gas background, furnace stack, or in other atmospheres with less than 10 percent oxygen. Further, these instruments should not be used where the oxygen concentrations exceeds that of fresh air (oxygen enriched atmospheres) because the extra oxygen makes any combustible mix easier to ignite and, thus, more dangerous.

Combustible gases will burn or explode only when the fuel/air mixtures are within certain proportions. The minimum concentration of a particular combustible gas in air that will burn and continue to burn when ignited is defined as the lower explosive limit (LEL). The maximum concentration that can be ignited is defined as the upper explosive limit (UEL). A small pump pulls the atmospheric sample through a filter and pushes it through the flow indicator and the manifold blocks in which the toxic gas, combustible gas and oxygen sensors are mounted. The flow is then exhausted to the side of the case. The approximate flow rate is 1.5 liters per minute.

To establish a zero background reading, the explosimeter should be prepared for operation in an area known to be free of combustible gases and vapors. A flush of fresh air should be passed through the instrument to zero the meter needle.

2.5 RADIATION DETECTORS

Radiation or radioactivity is the property of the nucleus of an atom to spontaneously emit energy in the form of high-energy electromagnetic waves or particles. Types of radiation that are of concern are alpha and beta particles, and gamma and X-radiation. Stable atoms of an element are composed of a dense nucleus containing an equal number of protons and neutrons. Surrounding the nucleus are clouds or orbits of electrons. The number of electrons in the atom of an element equals the number of protons. The number of neutrons in the atom can vary and, if it does, the atom is known as an isotope. Most isotopes are radioactive; they are unstable and tend to transform into an atom of a different element called a "daughter" by releasing a particle (either alpha or beta) or by emission of gamma and X-rays. The type of energy released and the rate of this release (decay rate or half-life) is particular to each isotope. An isotope can be identified by determining the type of energy released by measuring the decay rate. Radiation detectors operate on the principle that radiation causes ionization in the detection media. The ions produced are counted electronically, and a relationship is established between the number of ionizing events and the quantity of radiation present.

2.5.1 Alpha/Beta Survey Instrumentation

Surveys for alpha/beta radiation will be performed using a Ludlum Model 2360 Scaler/Ratemeter Data Logger equipped with a command device as well as a Ludlum Model 43-89 probe (or equivalent). The instrumentation measures alpha and beta radiation levels and presents data in a scaler (digital display) or ratemeter (analog display) mode. Static measurements for particulate type radiations are recorded by the ratemeter after positioning the detector, a scintillation probe, directly over a designated surveillance surface and determining a stationary measurement for a specified period of time. Scan measurements are obtained by traversing an area at a maximum speed (scan rate) of approximately 0.5 meters per second (m/s) and slowly sweeping the detector assembly in a serpentine (e.g., S-shaped) pattern, while maintaining the detector approximately 0.25 inches (6 millimeters) above the area being surveyed.

Detailed operating and calibration procedures for the specific meter and detector are supplied by the equipment manufacturer. Project-specific sampling and analysis plans will identify the manufacturer and model selected for the field application.

2.5.2 Gamma Survey Instrumentation

Surveys for gamma radiation will be performed using a Ludlum Model 2350-1 Data Logger equipped with a command device and a Ludlum Model 44-10 scintillation detector, which utilizes a 2-inch by 2-inch sodium-iodide (NaI) crystal (or equivalent). Capable of detecting gamma photon energies ranging from 60 kilo-electron volts (keV) to 3 mega-electron volts (MeV), the instrument is programmed to respond to the full spectrum of gamma photon energies. Static measurements for photon type radiation require positioning the detector assembly approximately 4 inches (10 centimeters [cm]) above the designated surveillance surface and completing a stationary measurement for a pre-determined period of time. Scan measurements are obtained by traversing a path at a maximum speed (scan rate) of approximately 0.5 m/s and slowly moving the detector assembly in a serpentine (e.g., S shaped) pattern, while maintaining the detector 2.5 to 4 inches (6 to 10 cm) above the area being surveyed. NaI scintillation detectors are very sensitive to gamma radiation and are ideal for locating elevated radiation levels.

Detailed operating and calibration procedures for the specific meter and detector are supplied by the equipment manufacturer. Project-specific sampling and analysis plans will identify the manufacturer and model selected for the field application.

2.6 DRAEGER HAND PUMPS AND DIRECT-READ COLORIMETRIC INDICATOR TUBES

The colorimetric tube and pump measure the concentrations of specific inorganic or organic vapors and of gases that cause a discoloration, which is proportional to the amount of material present. The detector tubes are specific for individual compounds, or groups of compounds, and require specific sampling techniques. This information is supplied with the tubes; it details the required sample volume, the proper tube preparation and insertion into pump, and the applicability and limitations of the individual tube. A known volume of air is drawn through a reagent using a pump. The compound reacts with the indicator chemical in the tube, producing a stain whose length or color change is proportional to the compound's concentration.

Some of the limitations are the measured concentration of the same compound may vary among different manufacturer's tubes. Many similar chemicals interfere. The tubes provide limited accuracy and results are dependent on the operator's judgment. Readings are affected by high humidity.

2.6.1 Operation

Do not use an opened tube. Complete a pump check at the beginning of each operational day. Check the pump for leaks before and after use by placing a tube into the suction inlet of the pump and completely depressing the bellows. The bellows should not completely extend in fewer than 30 minutes. Refrigerate the tubes prior to use to help maintain the shelf life. Always check the expiration date on the tubes prior to use. Break off both tips of the Draeger tube in the break-off eyelet located on the front pump plate. Tightly insert the tube into the pump head with the arrow pointing toward the pump head. If multiple tubes are used (i.e., vinyl chloride), join the tubes with the rubber tube provided, then insert the tube into the pump head. Fully compress the bellows and allow the bellows to re-extend until the chain is taut. Repeat as often as specified in the tube operating instructions. Evaluate the tube according to instructions.

2.6.2 Maintenance

Each unit on return from the field should be visually examined for surface dirt, deformities, cracks, and cuts. The pump integrity will be checked in the following manner:

- Block the inlet with an unopened tube.
- Fully compress; then release the pump bellows.

If the bellows do not completely fill (limit chain slack) in 30 minutes, the unit is operating properly. If the unit does not pass the leak test, proceed as follows:

- Remove the pump plate.
- Unscrew the valve with the special wrench provided.
- Clean the valve in water and dry.
- Replace the disc if it is sticky, brittle, hard, or cracked.
- Reassemble and retest.
- Calibrate the pump volume at least quarterly.

2.7 PHOTOIONIZATION DETECTOR (PID)

The PID is a portable instrument used to detect, measure, and provide a direct reading of the concentrations of a variety of trace organic gases in the atmosphere through photoionization. Procedures specific to this instrument are provided in SOP-54 Photoionization Detector.

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however, that each site and project is unique and these guidelines are not a substitute for common sense and good management practices based on professional training and experience. In addition, individual contract terms may affect the implementation of this SOP. TIMET contractors reserve the unrestricted right to change, modify or not apply these guidelines in their sole, complete, and unrestricted discretion to meet certain circumstances, contractual requirements, site conditions, or job requirements.

1.0 INTRODUCTION

All nondisposable field equipment must be decontaminated before and after each use at each sampling location to obtain representative samples and to reduce the possibility of cross-contamination.

1.1 PURPOSE

This Standard Operating Procedure (SOP) establishes the general requirements and procedures for decontaminating equipment in the field.

1.2 SCOPE

This SOP applies to decontaminating general nondisposable field equipment. To prevent contamination of samples, all sampling equipment must be thoroughly cleaned prior to each use.

1.3 DEFINITIONS

Alconox: Nonphosphate soap

2.0 PROCEDURE

The procedures below discuss decontamination of personal protective equipment (PPE), drilling and monitoring well installation equipment, borehole soil sampling equipment, water level measurement equipment, and general sampling equipment.

2.1 PERSONAL PROTECTIVE EQUIPMENT DECONTAMINATION

Personnel working in the field are required to follow specific procedures for decontamination prior to leaving the work area so that contamination is not spread off-site or to clean areas. All used disposable protective clothing, such as Tyvek coveralls, gloves, and booties, will be containerized for later disposal. Decontamination water will be containerized in 55-gallon drums. Personnel decontamination procedures will be as follows:

1. Wash neoprene boots (or neoprene boots with disposable booties) with Liquinox or Alconox solution and rinse with clean water. Remove booties and retain boots for subsequent reuse.

2. Wash outer gloves in Liquinox or Alconox solution and rinse in clean water. Remove outer gloves and place into plastic bag for disposal.

3. Remove Tyvek or coveralls. Containerize Tyvek for disposal and place coveralls in plastic bag for reuse.

4. Remove air purifying respirator (APR), if used, and place the spent filters into a plastic bag for disposal. Filters should be changed daily or sooner depending on use and application. Place respirator into a separate plastic bag after cleaning and disinfecting.

5. Remove disposable gloves and place them in plastic bag for disposal.

6. Thoroughly wash hands and face in clean water and soap.

2.2 DRILLING AND MONITORING WELL INSTALLATION EQUIPMENT DECONTAMINATION

All drilling equipment should be decontaminated at a designated location on-site before drilling operations begin, between borings, and at completion of the project. A decontamination area and clean zone will be established for the preparation and breakdown of equipment prior to each sampling task. The decontamination area will be large enough to accommodate equipment to be used for invasive work and allow decontamination rinsate to be pumped off for temporary storage and subsequent disposal.

Before use, and between each site, all equipment and other non-sampling equipment will be decontaminated with high pressure steam, or scrubbed with a non-phosphate detergent and rinsed with water from the approved water source. Monitoring well casing, screens, and fittings are assumed to be delivered to the site in a clean condition. However, they should be cleaned on-site prior to placement downhole. After cleaning the drilling equipment, field personnel should place the drilling equipment, well casing and screens, and any other equipment that will go into the hole on clean polyethylene sheeting (if appropriate). The drilling auger, bits, drill pipe, temporary casing, surface casing, and other equipment should be decontaminated by the drilling subcontractor by hosing down with a steam cleaner until thoroughly clean. Drill bits and tools that still exhibit particles of soil after the first washing should be scrubbed with a wire brush and then rinsed again with a high-pressure steam rinse. All wastewater from decontamination procedures should be containerized.

All equipment that may directly contact samples will be decontaminated on site. The following sampling-specific decontamination procedures will be observed:

1. Wash and scrub with detergent (laboratory grade - non-phosphate detergent).

2. Rinse with tap water.

3. Rinse with deionized water.

4. Rinse with deionized water.

5. Air dry.

6. Protect from fugitive dust and vapors.

Upon completion of the project, samples will be obtained from decontamination water resulting from final decontamination and demobilization of the equipment. Additional solvent and/or acid rinses may be added to the procedure, depending on the site sampling objectives. Materials Safety Data Sheets must be obtained for any hazardous chemicals used for decontamination and approved by the site safety officer prior to bringing the chemicals to the worksite. Personal protective equipment specific to the decontamination chemicals in use must be used, as specified in the health and safety plan. If these additional rinses are required, the procedures for incorporation are provided below:

1. Wash and scrub with detergent (laboratory grade - non-phosphate detergent).
2. Rinse with tap water.
3. Rinse with methanol (pesticide grade).
4. Rinse with deionized water.
5. Rinse with 1:1 nitric acid.
6. Rinse with deionized water.
7. Air dry.
8. Protect from fugitive dust and vapors.

2.3 BOREHOLE SOIL SAMPLING EQUIPMENT DECONTAMINATION

The soil sampling equipment should be decontaminated after each sample as follows:

1. Prior to sampling, scrub the split-barrel sampler and sampling tools in a bucket using a stiff, long bristle brush and Liquinox or Alconox solution.
2. Rinse the sampling equipment over the rinsate tub and allow to air dry.
3. Place cleaned equipment in a clean area on plastic sheeting and wrap with aluminum foil.
4. Containerize all water and rinsate.
5. Decontaminate all pipe placed down the hole as described for drilling equipment.

2.4 WATER LEVEL MEASUREMENT EQUIPMENT DECONTAMINATION

Field personnel should decontaminate the well sounder and interface probe before inserting and after removing them from each well. The following decontamination procedures should be used:

1. Wipe the sounding cable with a disposable soap-impregnated cloth or paper towel.
2. Rinse with deionized organic-free water.

2.5 GENERAL SAMPLING EQUIPMENT DECONTAMINATION

All nondisposable sampling equipment should be decontaminated using the following procedures:

1. Select an area removed from sampling locations that is both downwind and downgradient. Decontamination must not cause cross-contamination between sampling points.

2. Maintain the same level of protection as was used for sampling.

3. To decontaminate a piece of equipment, use an Alconox wash; a tap water wash; a solvent (methanol or hexane) rinse, if applicable or dilute (0.1 N) nitric acid rinse, if applicable; a distilled water rinse; and air drying. Use a solvent (methanol or hexane) rinse for grossly contaminated equipment (for example, equipment that is not readily cleaned by the Alconox wash). The dilute nitric acid rinse may be used if metals are the analyte of concern.

4. Place cleaned equipment in a clean area on plastic sheeting and wrap with aluminum foil.

5. Containerize all water and rinsate.

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1.0 INTRODUCTION

Soil sampling is conducted for three main reasons. First, samples can be obtained for laboratory chemical analysis. Second, samples can be obtained for laboratory physical analysis. Third, samples can be obtained for visual classification and field screening. These three sampling objectives can be achieved separately or in combination with each other. Sampling locations are typically chosen to provide chemical, physical, or visual information in both the horizontal and vertical directions. A sampling and analysis plan is used to outline sampling methods and provide preliminary rationale for sampling locations. Sampling locations may be adjusted in the field based on the screening methods being used and the physical features of the area.

1.1 PURPOSE

Soil sampling is conducted to determine the chemical, physical, and visual characteristics of surface and subsurface soils. The samples must not be contaminated by drilling fluids or by the sampling procedures. This guideline provides a description of the principles of operation, applicability, and implementability of standard soil sampling methods used during site investigations.

1.2 SCOPE

This Standard Operating Procedure (SOP) describes procedures for soil sampling in different areas using various implements. It includes procedures for test pit, surface soil, and subsurface soil sampling, and describes eight devices.

1.3 DEFINITIONS

Bucket auger: A type of auger that consists of a cylindrical bucket 10 to 72 inches in diameter with teeth arranged at the bottom.

Core sampler: Thin-wall cylindrical metal tube with diameter of 0.5 to 3 inches, a tapered nosepiece, a “T” handle to facilitate sampler deployment and retrieval, and a check valve (flutter valve) in the headpiece.

Hand auger: Instrument attached to the bottom of a length of pipe that has a crossarm or “T” handle at the top. The auger can be closed-spiral or open-spiral.

Sample Rings: Rings that fit snugly in standard split spoon samplers. Rings can be obtained in 3-, 6- and 12-inch lengths to retrieve the desired volume of soil aliquot.

Spatulas or Spoons: Stainless steel instruments for collecting loose unconsolidated material.

Split-Spoon (or Split-Barrel) Sampler: Thick-walled steel tube that is split lengthwise. A cutting shoe is attached to the lower end; the upper end contains a check valve and is connected to drill rods.

Thin-Wall Tube Sampler: Steel tube (1 to 3 millimeters thick) with tapered bottom edge for cutting. The upper end is fastened to a check valve that is attached to drill rods.

Trier: Tube cut in half lengthwise with a sharpened tip that allows for collection of sticky solids or loosening of cohesive soils.

Trowel: Tool with a scooped blade 4 to 8 inches long and 2 to 3 inches wide with a handle.

1.4 SELECT REFERENCES

Attached to this SOP are the following applicable American Society for Testing and Materials (ASTM) standard practices and guidelines related to soil sampling by various methods. The ASTM standards listed are considered an integral part of this SOP, and must be attached.

- D1452-80(2000) Practice for Soil Investigation and Sampling by Auger Borings
- D1586-99 Test Method for Penetration Test and Split-Barrel Sampling of Soils
- D1587-00 Practice for Thin-Walled Tube Geotechnical Sampling of Soils
- D3550-01 Practice for Ring-Lined Barrel Sampling of Soils
- D4220-95(2000) Practice for Preserving and Transporting Soil Samples
- D4547-06 Practice for Sampling Waste and Soils for Volatile Organics
- D4700-91 (2006) Guide for Soil Sampling from the Vadose Zone
- D5451-93(2004) Practice for Sampling Using a Trier Sampler

2.0 PROCEDURES

This SOP presents procedures for conducting test pit, surface soil, and subsurface soil sampling. The site sampling plan will specify which of the following procedures will be used. Soil samples for chemical analysis should be collected in the following order: (1) volatile organics, (2) semivolatile organics, and (3) all others. Once the chemical samples have been containerized, samples for physical analyses can be containerized. Typical physical analyses conducted include (1) grain size distribution, (2) moisture content, (3) saturated permeability, (4) unsaturated permeability, and (5) Atterberg limits. Additionally, visual descriptions of samples, using the Unified Soil Classification System (USCS), should be recorded (see SOP-52 Borehole Logging). Field tests such as head space analyses can also be conducted (see SOP-54 Photoionization Detector).

Soil samples for chemical analyses can be collected either as grab samples or composite samples. A grab sample is collected from a discrete location or depth. A composite sample consists of soil combined from more than one discrete location. Typically, composite samples consist of soil obtained from several locations and homogenized in a stainless steel or Teflon® pan or tray. Samples for volatile organic analysis (VOA) should not be composited.

2.1 TEST PIT SOIL SAMPLING

Test pit soil sampling is conducted when a complete soil profile is required or as a means of locating visually detectable contamination. This type of sampling provides a detailed description of the soil profile and allows for multiple samples to be collected from specific soil horizons. Prior to conducting any test pit or trench excavation with a backhoe, the sampling team should ensure that the sampling area is clear of utility lines, subsurface pipes, and poles. A test pit or trench is excavated by incrementally removing soil material with a backhoe bucket. The excavated soil is placed on plastic sheeting well away from the edge of the test pit. A test pit should not be excavated to depths greater than 4 feet unless its walls are properly stabilized.

Personnel entering the test pit may be exposed to toxic or explosive gases and oxygen deficient environments. Air monitoring is required before entering the test pit and the use of appropriate respiratory gear and protective clothing is mandatory (refer to project-specific Safety Plan). At least two persons must be present at the test pit before sampling personnel enter the excavation and begin soil sampling.

Test pits are not practical for depths greater than 15 feet. If soil samples are required from depths greater than 15 feet, samples should be obtained using soil borings instead of test pits. Test pits are also usually limited to a few feet below the water table. In some cases, a pumping system may be required to control the water level within the pits.

Access to open test pits should be restricted by use of flagging, tape, or fencing. If a fence is used, it should be erected at least 6 feet from the perimeter of the test pit. The test pit should be backfilled as soon as possible after sampling is completed.

Soil samples can be collected from the walls or bottom of a test pit using various equipment. A hand auger, bucket auger, or core sampler can be used to obtain samples from various depths. A trier, trowel, or spoons can be used to obtain samples from the walls or pit bottom surface.

2.2 SURFACE SOIL SAMPLING

The surface soil sampling equipment presented in this SOP is best suited for sampling to depths of 0 to 6 feet below ground surface (bgs). The sample depth, sample analyses, soil type, and soil moisture will also dictate the best suited sampling equipment. Prior to sample collection, the sampling locations should be cleared of any surface debris such as twigs, rocks, and litter. The following table presents various surface soil sampling equipment and their effective depth ranges, operating means (manual or power), and sample types collected (disturbed or undisturbed).

Sampling Equipment	Effective Depth Range (feet bgs)	Operating Means	Sample Type
Hand Auger	0 to 6	Manual	Disturbed
Bucket Auger	0 to 4	Power	Disturbed
Core Sampler	0 to 4	Manual or Power	Undisturbed
Shovel	0 to 6	Manual	Disturbed

Sampling Equipment	Effective Depth Range (feet bgs)	Operating Means	Sample Type
Trier	0 to 1	Manual	Disturbed
Trowel	0 to 1	Manual	Disturbed
Spoon/Spatula	0 to 0.5	Manual	Disturbed

The procedures for using these various types of sampling equipment are discussed below.

2.2.1 Hand Auger

A hand auger equipped with extensions and a "T" handle is used to obtain samples from a depth of up to 6 feet. A hand auger typically cuts a hole 3 to 9 inches in diameter. Actual maximum depth depends on soil conditions, buried obstructions, and groundwater levels. Generally, the borehole cannot be advanced below the water table because the hole collapses. If necessary, a shovel may be used to excavate the topsoil to reach the desired subsoil level. If topsoil is removed, its thickness should be recorded. Samples obtained via hand auger are disturbed in their collection; determining the exact depth at which samples are obtained is difficult.

The hand auger is screwed into the soil at an angle of 45 to 90 degrees from horizontal. When the entire auger blade has penetrated soil, the auger is removed from the soil by lifting it straight up without turning it, if possible. If the desired sampling depth has not been reached, the soil is removed from the auger and deposited onto plastic sheeting. This procedure is repeated until the desired depth is reached and the soil sample is obtained. The auger is then removed from the boring and the soil sample is collected directly from the auger into an appropriate sample container.

Hand augers are generally used to collect samples in situations where conventional drilling and soil sampling equipment can not access the area of interest or would damage the ground surface. They may also be used when a limited number of samples are to be collected and the cost of mobilizing conventional drilling equipment is not justified. Hand augers may be a one-piece design where the handle, extension rod, and auger head are permanently joined; or component design where the handle, extension rod, and auger head are screwed or pinned together. The component design allows additional extension rods to be added to achieve greater depth in the borehole. The component design also allows field personnel to attach various auger head styles appropriate for the soil type and conditions. Some typical auger head types and their recommended applications are listed below:

- Standard Bucket—The standard bucket auger head is a steel cylinder with cutting bits on the bottom and an arched brace on the top that attaches to the extension rod. The standard bucket auger is designed for sampling stony or dense soil that prohibits the use of a hand-operated core or screw auger. A bucket auger with closed blades is used in soil that cannot generally be penetrated or retrieved by a core sampler. The bucket auger is rotated while downward pressure is exerted until the bucket is full. The bucket is then removed from the boring, the collected soil is placed on plastic sheeting, and this procedure is repeated until the appropriate depth is reached and a sample is obtained. The bucket is then removed from the boring and the soil sample is transferred from the bucket to an appropriate sample container.

- Mud—The mud auger head is similar to the standard bucket auger except that it has openings cut in the side of the cylinder for easier removal of heavy, wet soil and clay rich samples.

- Sand—The sand auger head is also similar to the standard bucket auger but the bits are designed to better hold dry and sandy soils while the auger is being removed from the borehole.

- Planer—A planer auger has bits that are nearly flush with the auger head. This head is not intended to advance the borehole but is used to smooth the bottom and remove loose soil and debris left by the cutting heads.

- Gouge—Gouge augers have a half-cylindrical body designed for creating relatively undisturbed soils cores within the borehole.

- Screw—The screw-type auger head is similar to a typical auger-type drill bit. It does not have a cylinder for retaining cuttings or samples, and is intended primarily for creating small diameter holes.

- Dutch—The Dutch auger head also is used for advancing holes without recovering samples or cuttings. It is designed as a cutting head for advancing boreholes through wet, boggy soil and fibrous or heavily rooted soil.

Soil samples for geotechnical analyses should not be collected directly from a hand auger because the samples are disturbed. Hand auger samples for chemical analyses should be used with caution because the samples are generally disturbed and loss of volatile organic compounds (VOCs) may have occurred. Also, cross contamination of the sample may occur while inserting and removing the hand auger from the borehole. Samples for detailed chemical or geotechnical analyses should be taken with a sampling tool such as a drive sampler applied at the desired depth. For component hand augers, these types of sampling devices can be substituted for the auger head once the borehole has been advanced to the desired depth. The sampler can then be pushed or pounded into the undisturbed soil at the bottom of the borehole. However, the upper portion of the recovered sample should be discarded because it may be disturbed from the bit of the auger head or may contain debris that has fallen from the wall of the borehole. Samples for lithologic logging purposes may be taken directly from the hand auger.

2.2.2 Core Sampler

A hand-operated core sampler (Figure 1), similarly equipped as the hand auger, is used to obtain samples from a depth of up to 4 feet in uncompacted soil. The core sampler is capable of retrieving undisturbed soil samples and is appropriate when low concentrations of metals or organics are of concern. The core sampler should be constructed of stainless steel. A polypropylene core sampler is generally not suitable for sampling dense soils or sampling at an appreciable depth.

The core sampler is pressed into the soil at an angle of 45 to 90 degrees from horizontal and is rotated when the desired depth is reached. The core is then removed, and the sample is placed into an appropriate sample container.

2.2.3 Shovel

A shovel may be used to obtain large quantities of soil that are not readily obtained with a trowel. A shovel is used when soil samples from a depth of up to 6 feet are to be collected by hand excavation; a tiling spade (sharpshooter) is recommended for excavation and sampling. A standard steel shovel may be used for excavation; either a stainless steel or polypropylene shovel may be used for sampling. Soil excavated from above the desired sampling depth should be stockpiled on plastic sheeting. Soil samples should be collected from the shovel and placed into the sample container using a stainless-steel scoop, plastic spoon, or other appropriate tool.

2.2.4 Trier

A trier (Figure 2) is used to sample soil from a depth of up to 1 foot. A trier should be made of stainless steel or polypropylene. A chrome-plated steel trier may be suitable when samples are to be analyzed for organics and heavy metal content is not a concern.

Samples are obtained by inserting the trier into soil at an angle of up to 45 degrees from horizontal. The trier is rotated to cut a core and is then pulled from the soil being sampled. The sample is then transferred to an appropriate sample container.

2.2.5 Trowel

A trowel is used to obtain surface soil samples that do not require excavation beyond a depth of 1 foot. A trowel may also be used to collect soil subsamples from profiles exposed in test pits. Use of a trowel is practical when sample volumes of approximately 1 pint (0.5 liter) or less are to be obtained. Excess soil should be placed on plastic sheeting until sampling is completed. A trowel should be made of stainless steel or galvanized steel. It can be purchased from a hardware or garden store. Soil samples to be analyzed for organics should be collected using a stainless steel trowel. Samples may be placed directly from the trowel into sample containers.

2.3 SUBSURFACE SOIL SAMPLING

Subsurface soil sampling, in conjunction with borehole drilling, is required for soil sampling from depths greater than approximately 6 feet (or shallower depending upon geologic conditions). Subsurface soil sampling is frequently coupled with exploratory boreholes or monitoring well installation. Refer to SOP-51 and SOP-52 (Drilling Methods and Borehole Logging) and SOP-100 (Groundwater Monitoring Well Design and Installation).

Subsurface soil sampling may be conducted using a drilling rig or power auger. Selection of sampling equipment depends upon geologic conditions and the scope of the sampling program. Two types of samplers used with machine-driven augers— the split-spoon sampler and the thin-wall tube sampler— are discussed below. All sampling tools should be cleaned before and after each use in accordance with SOP-7 (Equipment Decontamination). Both the split-spoon sampler and the thin-wall tube sampler can be used to collect undisturbed samples from unconsolidated soils. The procedures for using the split-spoon and thin-wall tube samplers are presented below.

2.3.1 Split-Spoon Sampler

Split-spoon samplers are available in a variety of types and sizes. Site conditions and project needs such as large sample volume for multiple analyses determine the specific type of split-spoon sampler to be used. Split-spoon samplers are usually steel or stainless steel, are tubular in shape, and are split longitudinally into two semicylindrical halves. Figure 3 shows a generic split-spoon sampler. They may be lined or unlined. Liners are made of brass, aluminum, stainless steel, or various synthetic materials. Split-spoon samplers are generally available in 2-, 2.5-, 3-, 3.5-, and 4-inch outside diameters (OD). Lengths range between 12 and 60 inches. The 18-inch long sampler is the most commonly used.

Driving (hammering) is the usual method of obtaining split-spoon samples up to 2.5 feet in length. The split-spoon sampler is advanced into the undisturbed soil beneath the bottom of the casing or borehole using a weighted hammer and a drill rod. The relationship between hammer weight, hammer drop, and number of blows required to advance the split-spoon sampler in 6-inch increments correlates to the density or consistency of the subsurface soil. If the sampler cannot be advanced 6 inches with a reasonable number of blows (usually about 50), sampler refusal occurs and the sampling effort at that particular interval is terminated. If "auger refusal" has not occurred, the hole is advanced to the next sampling interval where another attempt at sample retrieval is made.

After the split-spoon sampler has been driven to its intended depth, it should be removed carefully to avoid loss of sample material. In noncohesive or saturated soil, a catcher or basket should be used to help retain the sample.

After the split-spoon sampler is removed from the casing, it is detached from the drill rod and opened. If VOA samples are to be collected, VOA vials should be filled with soil taken directly from the split-spoon sampler. Following sample description, sample material for non-VOC analyses may be composited, homogenized, or collected from discrete intervals as provided in the project-specific sampling and analysis plan. Care shall be taken to ensure that the sample collected is representative of the sample interval of interest,

2.3.2 Thin-Wall Tube Sampler

The thin-walled tube (Shelby tube) sampler is an 18-, 30-, or 36-inch long, thin-walled steel, aluminum, brass, or stainless steel tube equipped with a connector head (Figure 4). It is primarily used in soft or clayey formations where it will provide more sample recovery than a split-spoon sampler and when relatively undisturbed samples are desired. The most commonly used sampler has a 3-inch OD and a 2.81-inch cutting diameter, and is 30 inches long. Pressing or pushing without rotation is the normal mode of advance for the thin-walled sampler. If the tube cannot be advanced by pressing, it may become necessary to drive the sample with drill rods and hammers without rotation. The tubes are generally allowed to stay in the hole 10 to 15 minutes to allow the buildup of skin friction prior to removal. The tube is then rotated to separate it from the soil beneath it, prior to being brought to the surface.

After removal of the tube sampler from the drilling equipment, the tube sampler should be inspected for adequate sample recovery. The sampling procedure should be repeated until an adequate soil core is obtained (if sample material can be retained by the tube sampler). The soil core obtained should be documented in the logbook or on appropriate form (see SOP-3, Field

Documentation and SOP-52, Borehole Logging). Any disturbed soil is removed from each end of the tube sampler. If chemical analysis is required, VOA samples must be collected immediately after the tube sampler is withdrawn. Before use, and during storage and transport, the tube sampler should be capped with a nonreactive material. For physical sampling parameters, the tube sampler should be sealed at each end. The top and bottom of the tube sampler should be labeled and the tube sampler should be stored accordingly.

FIGURE 1
HAND-OPERATED CORE SAMPLER

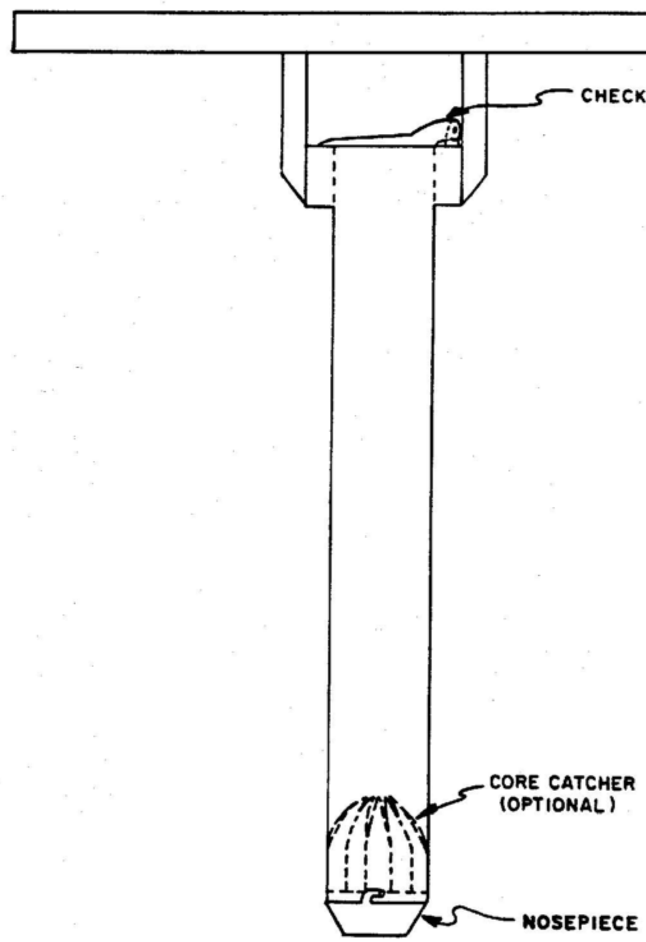


FIGURE 2
TRIER

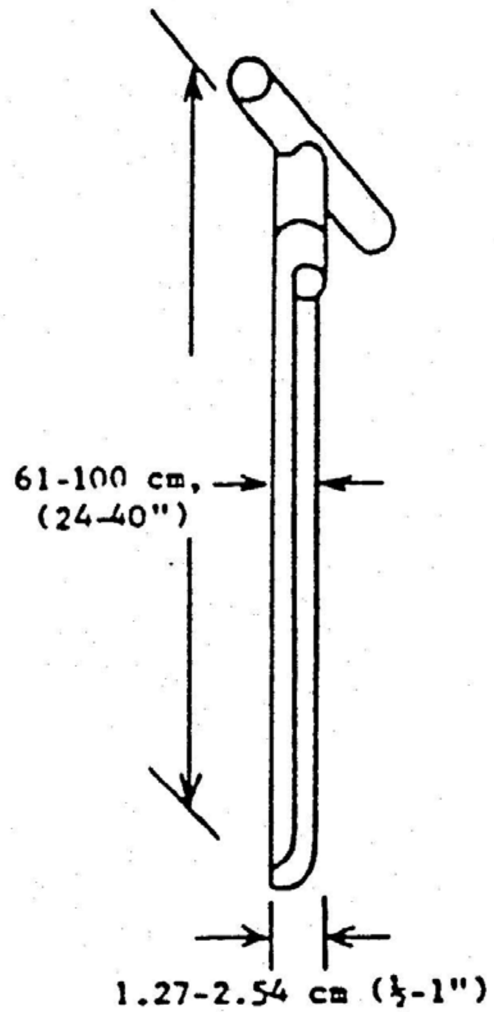


FIGURE 3
GENERIC SPLIT-SPOON SAMPLER

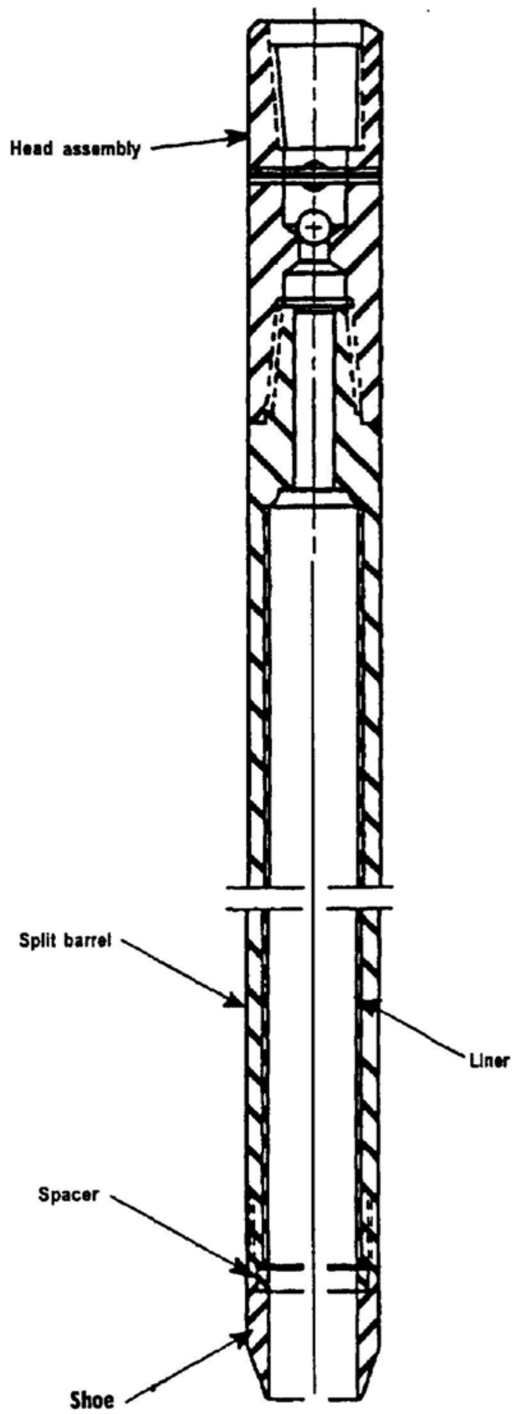
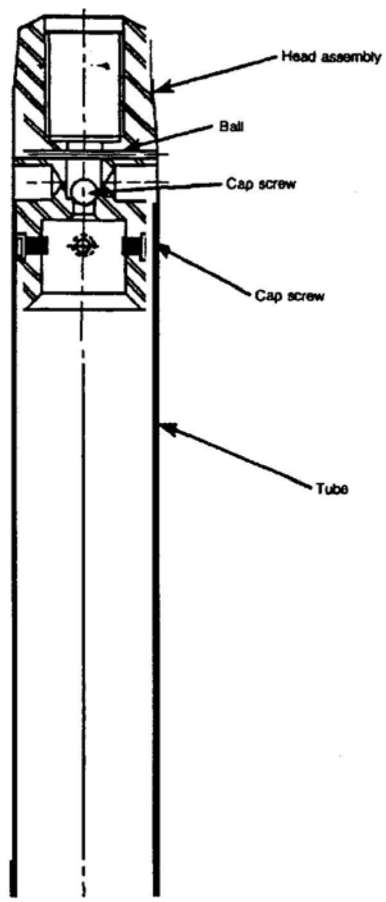


FIGURE 4
THIN-WALL TUBE SAMPLER



DISCLAIMER
This SOP provided general guidance for TIMET contractors and subcontractors for technical issues addressed during environmental site investigation and remediation activities. It is noted, however, that each site and project is unique and these guidelines are not a substitute for common sense and good management practices based on professional training and experience. In addition, individual contract terms may affect the implementation of this SOP. TIMET contractors reserve the unrestricted right to change, modify or not apply these guidelines in their sole, complete, and unrestricted discretion to meet certain circumstances, contractual requirements, site conditions, or job requirements.

1.0 INTRODUCTION

To determine the most appropriate drilling method for investigations or studies, primary consideration must be given to obtaining samples that are representative of existing conditions and are valid for chemical analysis. The samples must not be contaminated or adversely affected by the drilling method. Drilling associated with remedial actions, pilot studies, or treatability studies may include the installation of vapor or water extraction and/or injection wells. In electing the most appropriate drilling method for these projects, primary consideration must be given to completion of a well that will perform as designed.

1.1 PURPOSE

This Standard Operating Procedure (SOP) is designed to aid in the selection of appropriate drilling methods for site specific conditions. This SOP is intended to be used by the Project Manager (PM), Project Engineer (PE), Field Team Leader (FTL), and Site Hydrogeologist or Geologist to develop an understanding of each drilling method sufficient to plan, schedule, and perform the activities associated with drilling. This SOP focuses on methods and equipment that are readily available and typically applied. It is not intended to provide a comprehensive discussion of drilling methods. Two general drilling methods are discussed: (1) methods that do not use circulating fluids; and (2) methods requiring the circulation of drilling fluids to transport cuttings to the surface.

1.2 SCOPE

This SOP describes the principles of operation and the applicability of standard drilling methods used during field investigations.

1.3 DEFINITIONS

Bailer: A cylindrical tool designed to remove material, both solid and liquid, from a well or borehole. There are four types of bailers: ball-valve, flat-valve, dart-valve, and the sand pump with rod plunger.

Cone Penetrometer: An instrument used to determine and evaluate subsurface conditions by measuring the ratio of cone tip resistance to sleeve friction, and then comparing that ratio to a standardized set of ratios. The cone penetrometer can be fitted with other instruments that are able to determine pore pressure (the presence of groundwater), to detect contamination and identify the contaminant, and to determine other physical parameters of the sediment. The cone penetrometer consists of a conical point attached to a drive rod of smaller diameter. Penetration of the cone into the formation forces the soil aside, creating a complex shear failure. The cone penetrometer is very sensitive to small differences in soil consistency.

Cuttings: As a borehole is drilled, the subsurface material displaced by drilling and brought to the surface.

Drilling Fluids or Muds: A water-based or air-based fluid used in the well drilling operation to remove cuttings from the borehole, to clean and cool the bit, to reduce friction between the drill string and the sides of the borehole, to stabilize borehole walls, and to seal the borehole.

Dual-Purpose Well: A well that can be used as both a monitoring and extraction or injection well.

Flight: An individual auger section, usually 5 feet in length.

Heaving Formation: Unconsolidated, saturated substrate encountered during drilling where the hydrostatic pressure of the formation is greater than the borehole pressure causing the sands to move up into the borehole, and frequently causing drilling or well installation complications. Clean water or drilling muds may need to be introduced into the borehole to minimize or eliminate the potential for heaving.

Kelly Bar: A hollow steel bar or pipe that is the main section of drill string to which the power is directly transmitted from the rotary table to rotate the drill pipe and bit. The cross section of the Kelly is either square, hexagonal, or grooved. The Kelly works up and down through drive bushings in the rotary table.

Pitch: The distance along the axis of an auger flight that it takes for the helix to make one complete 360-degree turn.

Rotary Table: A mechanical or hydraulic assembly that transmits rotational torque to the Kelly, which is connected to the drill pipe and the bit. The rotary table has a hole in the center through which the Kelly passes.

Split-Spoon Sampler: A thick-walled, typically 18-inch long steel tube split lengthwise and used to collect soil samples. The sampler is commonly lined with brass or stainless steel sample sleeves and is driven or pushed downhole by the drill rig to collect samples.

Thin-Walled Sampler: A sampling devise used to obtain undisturbed soil samples made from thin-wall tubing. The sampler is also known as a Shelby tube. The thin-wall sampler minimizes the most serious sources of disturbance: displacement and friction.

1.4 REFERENCES

D6914-04e1 Standard Practice for Sonic Drilling for Site Characterization and the Installation of Subsurface Monitoring Devices

D1452 Practice for Soil Investigation and Sampling by Auger Borings

D3441 Test Method for Deep, Quasi-Static, Cone and Friction-Cone Penetration Tests of Soil

D5781 Guide to the Use of Dual-Wall Reverse-Circulation Drilling for Geoenvironmental Exploration and the Installation of Subsurface Water-Quality Monitoring Devices

D5782 Guide for the Use of Direct-Air Rotary Drilling for Geoenvironmental Exploration and the Installation of Subsurface Water-Quality Monitoring Devices

D5783 Guide for the Use of Direct Rotary Drilling with Water-Based Drilling Fluid for Geoenvironmental Exploration and the Installation of Subsurface Water-Quality Monitoring Devices

D5784 Guide for the Use of Hollow-Stem Augers for Geoenvironmental Exploration and the Installation of Subsurface Water-Quality Monitoring Devices

D5872 Guide for the Use of Casing Advancement Drilling Methods for Geoenvironmental Exploration and the Installation of Subsurface Water-Quality Monitoring Devices

D5876 Guide for the Use of Direct Rotary Wireline Casing Advancement Drilling Methods for Geoenvironmental Exploration and the Installation of Subsurface Water-Quality Monitoring Devices

D5875 Guide for the Use of Cable-Tool Drilling and Sampling Methods for Geoenvironmental Exploration and the Installation of Subsurface Water-Quality Monitoring Devices

2.0 PROCEDURE

Drilling methods can be separated into two general types: techniques that use circulating fluids and techniques that do not use circulating fluids. The following section discusses the drilling methods that fall into these two general categories.

2.1 METHODS WITHOUT CIRCULATING FLUIDS

There are two drilling methods that do not require circulating fluids: augering and percussion drilling. SOPs for each of these methods are described below.

2.1.1 Augering

Auger drilling is accomplished by rotating a pipe or rod that has a cutting bit. The common auger drilling methods discussed in this section are hand, continuous-flight, hollow-stem, and bucket.

2.1.1.1 Hand Auger

A hand auger typically cuts a hole 2 to 9 inches in diameter and, depending on the geologic materials, may be advanced to about 15 or 20 feet. Generally, the borehole cannot be advanced below the water table because the hole collapses. Soil samples for chemical or geotechnical analyses should not be collected directly from a hand auger because the samples are disturbed and cross contamination may occur. Samples for chemical or geotechnical analyses should be taken with a sampling tool such as a drive sampler driven at the desired depth. Samples for lithologic logging purposes may be taken directly from the auger.

<u>Advantages and Disadvantages</u>

- Shallow soil investigations
- Requires minimal access
- Soil sample collection
- Water-bearing zone identification
- Limited to shallow depths
- Unable to penetrate dense or rocky soil

- Borehole stability difficult to maintain
- Labor intensive

2.1.1.2 Continuous-Flight Auger

Continuous-flight augers consist of a plugged, tubular steel center shaft around which a continuous steel strip, in the form of a helix, is welded. An individual auger is known as a "flight" and is generally 5 feet long. Auger drill heads are generally designed to cut a hole 10 percent greater in diameter than the actual diameter of the auger they serve. In addition to diameter, augers are specified by the pitch of the auger and the shape and dimension of the connections.

<u>Advantages and Disadvantages</u>

- Shallow soils investigations
- Soil sample collection
- Vadose zone monitoring wells
- Groundwater monitoring wells in saturated, stable soils
- Identification of depth to bedrock
- Fast and mobile
- Soil sampling difficult and limited to areas of stable soils
- Difficult to build monitoring wells in unstable soils
- Depth capability decreases as diameter of auger increases
- Monitoring well diameter limited by auger diameter

2.1.1.3 Hollow-Stem Auger

Hollow-stem augers are used to advance the borehole when discrete soil samples are needed. The augers are advanced by applying downward pressure on the augers as they are rotated. Material is forced to the ground surface around the exterior of the auger (spiral flights bring soil to the ground surface) during drilling. Cuttings are brought to the surface and can be identified.

Hollow-stem augers are commonly used in unconsolidated materials to depths of approximately 150 feet. An advantage of this drilling method is that undisturbed soil samples can be collected and the augers act as a temporary outer casing when installing a monitoring well. The hollow-stem auger consists of (1) a hollow steel tube with 5-foot spiral flights and (2) a finger-type cutter head at the bottom of the lead auger (drill rods can be removed or inserted through the center of the auger assembly, facilitating soil sampling). A bottom plug can be inserted into the hollow center of the cutter head to prevent loose (unconsolidated) soil form coming up into the auger. This plug also has a pilot cutting head. The plug may be removed from the auger whenever a soil sample from below the cutter head is needed. The removable inner plug is the primary advantage of this drilling method. Withdrawing the plug while leaving the auger in place provides an open, cased hole into which samplers, down-hole drive hammers, instruments, casing, wire, pipe, or numerous other items can be inserted. Replacing the center bit and plug allows for continuation of the borehole.

Hollow-stem augers are specified by the inside diameter of the hollow stem, not by the hole size it drills. Hollow-stem augers are available with inside diameters of 2.5, 3.25, 3.375, 4.0, 4.25, 6.25, 6.625, 8.25, and 10.25 inches. The most commonly used sizes are 3.25 inches and 4.25 inches for 2-inch monitoring wells and 6.625 inches for 4-inch monitoring wells. The larger diameter augers, 8.25 and 10.25 inches, are not generally used for monitoring well installation, although they have been used for the installation of dual-purpose wells. Drilling speed with hollow-stem augers is dependent upon the types of materials encountered. Heavy formations such as "fat" clays should be drilled at 30 to 50 revolutions per minute (rpm). Good clean sand that will stand open can be successfully augered at 75 rpm.

Lithologic sampling is accomplished by removing the center plug form the auger stem and placing the sampling device at the end of the drill-rod assembly. The drive stem is inserted through the hollow-stem auger and driven ahead of the augered material by a rig mounted, weighted hammer.

Considerations

Hollow-stem augering allows for drilling through soils below the water table with minimal cross-contamination. However, sediments such as flowing sands may "blow up" into the augers. If this situation in encountered (or will be known to occur), water of known chemical quality may be used to control sediment inflow. This method provides a greater head on the drilled sediments and prevents materials form advancing up through the auger.

The borehole should be advanced without using water unless absolutely necessary. Use of water while advancing through the unsaturated zone should not be necessary. If water is added during boring, it should be obtained from a source that has been analyzed and shows no contamination. If a lithologic sample is to be obtained, the borehole will be advanced by alternately boring a specified interval, removing the drive stem and bit, reinserting the drive stem with a sampler attached, and obtaining the sample. This procedure is continued until the desired depth is reached.

The auger stem, drive stem, and bit will be decontaminated prior to boring at a borehole location. At a minimum, this will include steam cleaning of the auger and drive stem. If a discrete zone of contamination is encountered during drilling, and drilling is to advance through this zone, downhole tools in contact with the contaminated zone will be steam cleaned after boring has proceeded through the contaminated interval. Additionally, to prevent downhole cross-contamination, it may be advisable to install an outer casing, grout the borehole while withdrawing the auger, redrill the hole through the grout using an auger with a smaller diameter auger, and then further advance the borehole.

The rotation of the augers causes the cuttings to move upward and "smear" along the borehole walls. This smearing may effectively seal off the upper zones, thereby reducing the possibility of cross contamination of the upper zones to the deeper zones, but increases the possibility of deep to shallow contamination.

<u>Advantages and Disadvantages</u>

- The boring depth is generally less than 100 feet in depth

- Permits good soil sampling with split-spoon or thin-wall samplers
- Monitoring well installation in all unconsolidated formations
- Can serve as temporary casing
- Can be used in stable formations to set surface casing
- Difficulty in preserving sample integrity in heaving formations
- Formation invasion by water or drilling mud if used to control heaving
- Possible cross contamination of aquifers where annular space not positively controlled by water or drilling mud or surface casing
- Limited diameter of augers limits casing size
- Smearing of clays may seal off aquifer to be monitored thus limiting free flow of fluids into the wells and decreasing the response to hydraulic tests

2.1.1.4 Bucket Auger

Bucket augers have a depth capacity of 30 to 75 feet and are used for large diameter holes (16 to 48 inches). Most bucket augers are “gravity fed” and are used for vertical holes. They are not normally used to drill monitoring wells or for soil sampling but may be used to drill production and recovery wells. Bucket augers may also be used to set conductor or surface casings for production wells. Generally, the auger bucket advances into the formation by combination of dead weight and the tooth cutting angle. The auger cuts into the formation approximately 1 to 2 feet at a time, filling the auger bucket. The bucket is attached to the lower end of a Kelly bar that passes through and is rotated by a large ring gear that serves as a rotary table. The Kelly is square in cross section and consists of two or more lengths of square tubing, one length telescoped inside the other. When the bucket is withdrawn from the hole by means of a wire-line hoist cable, it is swung to the side of the hole and the spoil is dumped out through the bottom by means of a hinge and latch device on the bucket bottom.

<u>Advantages and Disadvantages</u>

- Drilling of large diameter boreholes to a maximum depth of 75 feet
- Drilling in unconsolidated formations
- Difficult to advance the borehole below the water table
- Consolidated formations and cobbles are difficult to drill
- Loose sand formations may slough during drilling
- Undisturbed soil sampling difficult to achieve

2.1.2 Percussion Drilling

The basic method of advance in percussion drilling is hammering, striking, or beating on the sediments or formation. Common percussion methods that do not use circulating fluids are cabletool, driven boreholes, and sonic drilling.

2.1.2.1 Cable-Tool Drilling

Cable tool drilling uses a heavy, solid steel, chisel-type drill bit suspended on a steel cable that, when raised and dropped repeatedly, it chiselsor pounds a hole through the soil and rock. Cable tool rigs can operate satisfactorily in all formations, but they are best suited for large, caving, gravel-type formations with cobbles or boulders, or for formations with large cavities above the water table. These unconsolidated sediments require drilling with a temporary casing following the drill bit. The casing will prevent cave-in so the borehole can remain open. The drill bit breaks or crushes the formation. In unconsolidated formations, the drill bit primarily loosens the formation when drilling. In both instances, the reciprocating action of the tools mixes the crushed or loosened particles with water to form a slurry or sludge at the bottom of the borehole.
In dry stratigraphic horizons, water (from an analyzed approved source) can be introduced to the borehole. Slurry accumulation increases as drilling proceeds and eventually it reduces the impact of the tools. When the drop of the string of tools is hindered by the thickened slurry, the slurry is removed by a bailer. Removing the slurry will increase the efficiency and impact of the drill bit. In wet horizons, additional water is unnecessary.

Most boreholes drilled in unconsolidated formations are drilled "open hole;" that is, no casing is used during part or all of the drilling operation, athough, drilling with a casing may be necessary to prevent cross contamination of strata.

Drilling in unconsolidated formations differs from hard-rock drilling as pipe or well casing must follow the drill bit closely as the well is deepened to prevent caving and to keep the borehole open. Drilling rates of 20 to 100 feet per day are typical with the average being approximately 50 feet per day. Holes much smaller than 6 inches are impractical because of the need for a relatively large, heavy bit.

For monitoring well installation, borehole advancement will proceed to the desired depth. Appropriate well screen and inner casing will be set through the outer casing, and a centralizer will be used to anchor the screen in the annular space below the casing depth. The casing will then be withdrawn and appropriate sand/gravel packing and grout will be installed through the outer casing.

The downhole drill assembly and casing will be decontaminated prior to boring at another borehole location. At a minimum, this will include steam cleaning of equipment and casing. If a discrete zone of contamination is encountered during drilling, and drilling is to advance through this zone, downhole tools in contact with the contaminated zone will be steam cleaned after boring and drive casing has proceeded through the contaminated interval. At all times when subsurface contamination is encountered or suspected, casing will be driven as drilling proceeds.

<u>Advantages and Disadvantages</u>

- Drilling in all types of geologic formations

- Almost any depth and diameter range
- Relatively large casing diameter is required
- Drilling relatively slow
- Heaving of unconsolidated materials must be controlled
- Ease and practicality of well development
- Excellent samples of geologic materials
- Equipment availability more common in central, north central and northeast sections of the United States

2.1.2.2 Driving

A borehole can be constructed by driving a solid probe or plugged pipe into the ground. The information obtained by this technique can be either minimal or extensive. Driven wells, commonly referred to as wellpoints, are driven into the ground by hand or with heavy drive heads mounted on a tripod, drill rig derrick, or similar hoisting device. Wellpoints consist of a wellpoint (screen) that is attached to the bottom of a casing. Wellpoint and casing diameters generally range from 1.25 to 2 inches. Depths of 30 feet can be achieved by hand in sands or sands and gravels with thin clay seams. Depths of 50 feet or more can be achieved in loose soils with hammers weighing up to 1,000 pounds.

Driving through dense silts and clays and/or bouldery silts and clays is often extremely difficult or impossible. The well point may not be structurally strong enough and may be damaged or destroyed by driving through dense soils. Additionally, the screen may become plugged when driving through silts and clays and may be very difficult to reopen during development. Soil samples cannot be collected during this process; however, crude stratigraphic information may be obtained by recording the number of blows per foot of penetration. Driven wells or well points are usually installed for the collection of groundwater samples and the determination of static water levels to establish the regional groundwater gradient. A large track-mounted backhoe (CAT 245) has been used to install extraction wells in a landfill to the 30-foot depth. The bucket of the backhoe is used to push a 6-inch diameter drive pipe with a plugged bottom. When the drive pipe reaches the final depth for the well, the plug at the bottom of the drive pipe is removed and the well screen and casing materials are placed inside the drive pipe. A large 50-ton crane then pulls the drive pipe, leaving the well materials in the borehole. This technique is highly dependent upon the geologic formation and required depth.

The drive pipe pushes the formation aside. This can cause a compaction of the formation, which could impact the performance of the well. Considerably more information can be obtained by driving a penetrometer or a Dutch Cone. Penetration of the soil with a cone forces the soil aside, creating a complex shear failure. The degree of resistance yields the geologic logs of the borehole. Penetrometers can also obtain groundwater samples and possibly soil samples. The borehole that the penetrometer makes is usually abandoned; however, occasionally a small-diameter piezometer can be constructed within the borehole.

<u>Advantages and Disadvantages</u>

- Drilling of a borehole when soil samples are not needed
- Installation of a shallow well point when there are site access and work place limitations
- Geologic formations must be conducive for driven wells
- Driven wells should be limited to shallow wells
- Formation compaction usually occurs that can affect well production

2.1.2.3 Sonic Drilling

Sonic drilling, also known as resonance drilling, is a percussion drilling technique that uses a high-frequency drive hammer. The frequency of the drive hammer varies from 150 to 250 hits per minute. The drive pipe is either closed bottom or fitted with a soil sampling tube. If the bottom of the drive pipe is closed, the borehole is made without the removal of any formation. Instead, the formation is literally pushed to the side and out of the way of the drive pipe, which acts as well casing as the boring proceeds. The high frequency of the hammer tends to liquefy the formation in the vicinity of the bit, thus reducing the degree of difficulty of pushing pipe into the formation.

A soil sampling device, such as a split-spoon sampler or a core barrel, can be placed inside the drive pipe in lieu of the end plug. The sampler is removed at 5- or 10-foot intervals and replaced with an empty sampler. This procedure yields a continuous soil sample and produces minimal waste as only the formation within the sampler is brought to the surface. A monitoring well can be installed in the borehole by removing the sampler and setting the well screen and casing inside the drive pipe. The drive pipe is then withdrawn. This drilling technique again pushes the formation aside to create the borehole. Certain formation compaction can occur which could impact the performance of a well. Additionally, the rate of penetration of the drive pipe is very high, producing considerable heat at the bit on the drive pipe and within the sampler. The heat in the sampler may have a detrimental effect on soil samples for chemical analysis.

<u>Advantages and Disadvantages</u>

- Rapid drilling technique especially in difficult drilling formations
- Very limited equipment availability
- Heat generated with drive pipe can impact chemical concentrations
- Use when drilling in contaminated areas and disposal costs for wastes are high
- Can obtain continuous core compromise soil samples
- Formation compaction usually occurs that can affect well production

2.2 METHODS WITH CIRCULATING FLUIDS

Many drilling techniques use a circulating fluid, such as water or drilling mud, gas such as air, or a combination of air, water, and a surfactant to create foam. Circulation fluids flow from the surface either through the drill pipe, out through the bit, and up the annulus between the borehole wall and the drill pipe (direct rotary) or down the borehole annulus, into the bit, and up the drill pipe (reverse rotary). Generally, the up-hole velocity needed to transport cuttings to the surface is between 100 to 150 feet per minute for plain water with no additives, 80 to 120 feet per minute for high-grade bentonite drill muds, 50 to 1,000 feet per minute for foam drilling, and up to 3,000 feet per minute for air with no additives. Additives decrease the required minimum velocity. Excessive velocities can cause erosion of the borehole wall. The use of circulating fluids may involve the addition of chemicals to the borehole. Drilling mud utilizes bentonite clay and possibly polymers. Additives to air drilling may include surfactants (detergents) and water mist to generate foam. Compressed air may also contain various amounts of hydrocarbon lubricants. Therefore, attention should be given to the circulating fluids and any possible additives that are used when using drilling methods utilizing circulation fluids.

2.2.1 Rotary Drilling Methods

Rotary drilling methods require the rotation of the drill pipe and the drill bit to advance the borehole. The common drilling methods that use circulating fluids to remove the drill cuttings from the borehole are presented in the following sections.

2.2.1.1 Conventional Mud Rotary Drilling

In conventional mud rotary drilling, the circulating fluid is pumped through the rotating drill pipe and out of ports or jets in the bit. The fluid then flows up the annulus between the borehole and the drill pipe, carrying the drill cuttings in suspension to the surface. At the surface the fluid is directed into a circulation pit or tank where the cuttings settle out. The circulating fluid is then picked up with the mud pump and again directed downhole. Bentonite is usually added to water to make the drilling mud or fluid. The functions of the drilling fluid are to:

- Lift the cuttings from the bottom of the borehole and carry them to a settling pit
- Support and stabilize the borehole wall to prevent caving
- Seal the borehole wall to reduce fluid loss
- Cool and clean the drill bit
- Allow the cuttings to drop out in the settling pit
- Lubricate the bit, cone bearings, mud pump, and drill pipe

The drill string usually consists of four parts: (1) the bit, (2) one or more drill collars or stabilizers, (3) one or more lengths of drill pipe, and (4) a table-drive machine, the Kelly. Two general types of bits are used: the drag bit and the roller cone bit, usually called a rock bit. Nozzles or jets on the drill bit direct drilling fluids across cutting surfaces to clean and cool them. Reamer bits are used when hole enlargement, straightening, or cleaning becomes necessary.

Drilling pipe is seamless tubing usually manufactured in 20-foot lengths, although other lengths are available. Each joint has a tool-joint pin on one end and tool-joint box on the other. Pipe outside diameters range from 2-3/8 to 6-inches. Direct rotary machines use either a table-drive or a top-head drive system for rotating the drill string. In both systems, the driller can determine the rotation speed and pull-down pressure applied to the bit for the resistance of the formation and the rate of penetration.

Lithologic sampling is accomplished by removing the drill string from the hole, removing the drill bit, and placing a split-spoon sampler on the end of the drill system.

Direct mud rotary drilling can be used for all types of sediment and bedrock. In addition to cooling the drill bit and carrying the cuttings to the surface, drilling muds seal, support, and stabilize the borehole wall to prevent caving and fluid loss. These characteristics make this rotary technique particularly attractive for rapid drilling through poorly consolidated sediments or highly fractured bedrock. However, drilling muds should be selected carefully because they can adversely affect the chemistry of the ground water, subsequent ground-water samples, or operation of the well.

For effective rotary drilling, the down force on the bit should be great enough to cause continuous penetration of the boring. The pounds per inch of bit weight depends upon the configuration of the bit and the formation being penetrated. Rotary speeds are generally in the range of 60 to 200 rpm.

Advantages and Disadvantages

- Rapid drilling of clay, silt, and reasonably compacted sand
- Allows split-spoon and thin-walled samples in unconsolidated materials
- Allows core sampling in consolidated rock
- Drilling rigs widely available
- Abundant and flexible range of tool sizes and depth capabilities
- Very sophisticated drilling and mud programs available which requires knowledge and experience
- Difficult to remove drilling mud and wall cake from borehole wall during development
- Bentonite and other drilling additives may alter formation chemistry
- Circulated samples poor for monitoring well screen selection
- Split-spoon and thin-wall samplers are expensive and of questionable cost effectiveness at depths greater than 150 feet
- Difficult to identify aquifers
- Drilling fluid invasion of permeable zones may compromise validity of subsequent monitoring well samples

2.2.1.2 Air Rotary Drilling

Operational procedures and drill rig components used in direct air rotary drilling are similar to those used in the mud rotary method. However, in the direct air rotary method, compressed air lifts the cuttings from the borehole as opposed to the water-based fluids in mud rotary drilling. The compressed air is forced down the drill pipe, escapes through small ports at the bottom the drill bit, thereby lifting the cuttings and cooling the bit. The cuttings are blown out the top of the borehole and collect at the surface around the borehole. The up-hole velocity of the air and cuttings should be approximately 3,000 feet per minute. Injecting a small volume of water or foaming compound into the air system controls dust, enhances the air's lifting ability, and lowers the temperature of the air so that the swivel is cooled. The air rotary drilling method is primarily used in consolidated formations due to the fact that the rapidly rising cuttings would cause considerable erosion of the borehole wall in unconsolidated formations. With the air rotary drilling method, the circulating fluid is not reused again. The compressed air on the rig should be thoroughly filtered to ensure that compressor oil is not introduced into the groundwater aquifer. The following are functions of the drilling fluid:

- Lifting the cuttings from the bottom of the borehole and carrying them to the surface
- Cooling and cleaning the drill bit
- Lubricating the bit, cone bearings, mud pump, and drill pipe

The drill string used in air rotary drilling is similar to that used on mud rotary rigs. Roller-type rock bits up to 12 inches in diameter are commonly used when drilling with air; however, larger sizes are available. Rotary speeds are generally in the range of 75 to 200 rpm. If the hardness of the formation increases to the point that roller-cone rock bits cannot successfully penetrate the formation, then a down-hole air hammer is used to penetrate the formation. The rotating speed using the downhole air hammer is in the range of 15 to 30 rpm.

<u>Advantages and Disadvantages</u>

- Rapid drilling of semi-consolidated and consolidated rock
- Contaminated solids or water blown out of the hole are difficult to contain
- Equipment generally available
- Allows easy and quick identification of lithologic changes
- Allows identification of most water bearing zones
- Allows estimation of yields in strong water-producing zones with short "down time"
- Surface casing frequently required to protect top of hole
- Drilling restricted to semi-consolidated and consolidated formations
- Samples reliable but occur as small particles that are difficult to interpret

- Drying effect of air may mask lower yield water producing zones
- Air stream requires contaminant filtration
- Air may modify chemical or biological conditions. Recovery time uncertain

2.2.1.3 Air Rotary Casing Hammer (Drill and Drive)

Air rotary casing hammer method combines percussion and air rotary drilling methods to drill in unconsolidated formations. The borehole is drilled with the air rotary drilling method. Casing or drive pipe follows closely behind the rotary bit to prevent the erosion of the borehole wall. The casing is driven similar to a pile driver except for a hole through its axis through which a drill pipe is inserted and rotated. The drill bit is usually extended approximately 1-foot below the bottom of the drive pipe that acts as temporary casing.

Advantages and Disadvantages

- Rapid drilling of unconsolidated sands, silts, and clays
- Drilling in alluvial materials (including boulder formations)
- Casing supports borehole thereby maintaining borehole integrity and minimizing inter-aquifer cross contamination
- Eliminates circulation problems common with direct mud rotary method
- Good formation samples
- Minimal formation damage as casing pulled back
- Thin, low pressure water bearing zones easily overlooked if drilling not stopped at appropriate places to observe whether or not water levels are recovering
- Samples pulverized as in all rotary drilling
- Air may modify chemical or biological conditions
- Difficult to obtain soil samples for chemical analysis

2.2.1.4 Center Stem Recovery Rotary Drilling (Reverse Circulation)

In reverse circulation drilling, the circulating fluid (water) flows from the surface down the borehole annulus outside the drill pipe, into the drill bit, and up the inside of the drill pipe to ground surface. The fluid carries the cuttings to the surface and discharges them into a settling pit or tank. Reverse circulation is especially advantageous in very large boreholes and also in those cases where the erosive velocity of conventional rotary circulation would be detrimental to the borehole wall. Drilling is accomplished typically with water without additives. A large and dependable water supply is required to keep the borehole full of drilling fluid to maintain sufficient hydrostatic head on the borehole walls to prevent sloughing. Reverse circulation has few applications in monitoring work except when nested wells are desired. Production wells with 18- to 24-inch-diameter casing are typically drilled by the reverse circulation drilling method. Typical borehole diameters range from 15 to 36 inches; however, 60-inch-diameter boreholes are not uncommon.

Advantages and Disadvantages

- Large capacity production wells
- Nested wells
- Normally does not use drilling muds (little if any mud cake is formed on the wall of the borehole)
- Drills best in unconsolidated sands, silts, and clays
- Requires large and dependable source of water during drilling and well installation
- Cobbles and bedrock are difficult to drill

2.2.1.5 Dual-Tube Rotary

Dual-tube rotary is an exploratory drilling technique utilizing two concentric drill pipes. Both drill pipes are rotated during drilling. The outside of the outer drill pipe is typically 4.5 inches in diameter. The diameter of the borehole is approximately 5 inches. Compressed air is forced between the two drill pipes and is directed to the center pipe at the bit. The cuttings are carried to the surface by the returning air at a velocity of approximately 3,000 feet per minute. This is an excellent drilling method to identify lithology and the locations of aquifers in deep boreholes. It is very difficult to obtain undisturbed soil samples for chemical or geotechnical analyses; however, groundwater samples can be obtained as aquifers are encountered. Geophysical logs can be obtained if the borehole is filled with drilling mud as the drill pipe is removed. Monitoring wells are typically not installed in dual-tube rotary boreholes unless the borehole is reamed out by the mud rotary method. Depths of 1,000 feet are not uncommon for this drilling method and typically, the more consolidated the formation, the better the drilling, as unconsolidated formations cause more drag or friction on the outside of the rotating drill pipe.

Advantages and Disadvantages

- Used mostly for exploratory boreholes
- Rapid extraction of drill cuttings from the borehole
- Drill cuttings are representative of formation
- Very rapid penetration rate in all formations
- Can collect groundwater samples as aquifers are encountered
- Equipment availability
- Cannot obtain undisturbed soil samples for chemical analysis

- Borehole size is limited (5 inches)

2.2.2 Dual-Tube Percussion Drilling

Dual-tube percussion drilling is very similar to dual-tube rotary drilling with the exception that the two drive pipes do not rotate during drilling. Two concentric drive pipes are driven into the ground with a hammer. The hammer is similar to units on pile drivers. The typical outside diameter of the outer drive pipe is 9 to 12 inches. The typical inside diameter of the inner pipe, where well materials would be inserted, is 6 to 8 inches. This drilling system is also a center stem recovery system. This drilling technique has been developed and is used primarily in hazardous waste investigations. This method is rapid and effective to depths of about 250 feet.

The outer pipe effectively seals off the formation while drilling, reducing the chance of cross contamination. Air is pumped between the annulus of the two pipes to the bit where it is deflected upward into the center pipe. Cuttings are transported to the surface through the center pipe. In general, three systems are available: 7-inch outside diameter (OD)/4.25-inch inside diameter (ID), 9-inch OD/6-inch ID, and 12-inch OD/8-inch ID. A 2-inch-diameter monitoring well can be constructed in the 7-inch system, a 4-inch-diameter monitoring well can be constructed in the 9-inch system, and a 5- or 6-inch-diameter monitoring well can be constructed in the 12-inch system.

<u>Advantages and Disadvantages</u>

- Very rapid drilling through both unconsolidated and consolidated formations
- Allows continuous sampling for lithologic logging in all types of formations
- Very good representative samples can be obtained with minimal risk of contamination of sample and/or water bearing zone
- In stable formations, wells with diameters as large as 6 inches can be installed in open hole completions
- Soil samples can be easily obtained for chemical analysis
- Limited borehole size that limits diameter of monitoring wells
- In unstable formations wells are limited to approximately 4 inches
- Equipment availability more common in the southwest
- Air may modify chemical or biological conditions; recovery time is uncertain

2.2.3 Suction Drilling

Suction drilling has been used to drill into consolidated formations that yield little if any groundwater. This is an experimental drilling method that has been used by the U.S. Geological Survey (USGS) to drill in basalts in Idaho. The drilling technique is very similar to the reverse circulation drilling technique discussed in Section 4.2.1.4 with the exception that air is circulating, not water. To drill the borehole, a drill rig rotates a modified air rotary bit at the end of the drill pipe. The cuttings are removed by the suction from a high-pressure, high-volume air and steam ejector/eductor siphon system. The suction is directed to the interior of the drill pipe. All formation cuttings, including formation fluids, are brought to the surface via the interior of the drill pipe. To drill a 10-inch-diameter borehole, two 600 cubic feet per minute (cfm)/250 pounds per square inch (psi) air compressors are connected parallel to the ejector/eductor siphon device. Suction from the siphon device is directed to the 2-3/8-inch-diameter drill pipe. A 1.5-horsepower blower fan is used to direct air down the borehole.

<u>Advantages and Disadvantages</u>

- Allows continuous sampling for lithologic logging
- Very good representative samples can be obtained
- Drilling is not impeded in fractured formations that typically cause lost circulation problems
- Formations must be very consolidated to prevent the borehole wall from sloughing during drilling
- Cuttings are very abrasive to the drill pipe and discharge lines
- Difficult to maintain an adequate vacuum as air leaks form easily at threaded joints of the drill pipe
- Groundwater could prevent the advancement of the borehole

Drilling contractors have had numerous mechanical problems advancing boreholes beyond the 150-foot depth. Vacuum leaks have caused a loss in suction and the plugging of the drill pipe. The drill pipes have twisted off and the abrasive cuttings have worn holes in hoses and pipes. This drilling method has some unique advantages; however, until the mechanical problems are solved, this technique will not be available for use.

3.0 CONSIDERATIONS FOR SELECTION OF DRILLING METHODS

Each project or drilling site has its own considerations for the selection of a particular drilling method. Prior to selecting a drilling method, several factors must be considered. The major factors that this section will address include the objective of the drilling program, site conditions, and wastes generated. Other factors include drilling costs, availability of trained crews and appropriate equipment, and project schedule requirements. Recognize that it may be very difficult to fulfill all of the sampling/drilling objectives with a single drilling method. The drilling method selected may compromise some of the objectives of the drilling program.

3.1 DRILLING OBJECTIVES

The primary consideration in selecting any drilling method is to ensure the selected method is capable of meeting the objective(s) of the drilling/sampling program. It is common to have more than one objective for the drilling/sampling program and it may be difficult to satisfy all of the program objectives. For example, if sample collection (soil or groundwater) is the objective, the selected method must be capable of collecting, in an appropriate and approved manner, the necessary samples. Additionally, the contaminants of concern may influence the drilling and sampling method. Alternatively, if the objective of the drilling program is to install vapor or groundwater extraction wells, the selected method must be suitable for the installation of the designed well. It is important to not only consider the physical limitations of a particular drilling technique (i.e., depth and diameter), but examine the consequences of the drilling method with the drilling objective (i.e., smearing of the borehole walls rendering wells ineffective or inefficient).

3.2 SITE CONDITIONS

Site conditions can limit the drilling methods available for a particular program. Site conditions to be considered include both subsurface and surface conditions.

3.2.1 Subsurface Conditions

The subsurface stratigraphy of a site is a fundamental consideration when selecting a particular drilling method. The drilling equipment selected must be capable of effectively and economically penetrating the strata at the site to meet the project objectives. Particular stratigraphy that may pose problems for certain drilling methods include tight clayey soils, swelling clays, flowing sands, caliche, gravels, cobbles, lost circulation zones, and bedrock. In addition to stratigraphy, the site hydrology must also be considered. If multiple water-bearing zones are expected, a conductor casing may be needed to seal off shallow water-bearing zones and prevent potential cross contamination. The need for conductor casings can affect the selection of a particular drilling method. Wells that deeply penetrate aquifers can also affect the selection of a particular drilling method.

3.2.2 Surface Conditions

Surface conditions can affect access to the site and the amount of available work space (both horizontal and vertical or overhead space). These in turn can affect the selection of a particular method or type of drill rig. Limited access and work space may require smaller or remotely powered drill rigs. The site terrain is a very important factor in choosing the drilling method as it is very expensive and difficult to mobilize large and/or heavy equipment over rugged terrain. For sites such as these, drill rigs (typically hollow-stem auger) are mounted on all-terrain equipment.

In addition to access and work space, the work environment must also be considered. This includes both weather and other site activities. Extremely hot or cold climates may require use of special drilling equipment or methods. Sites such as refineries where explosive atmospheres could exist may also require very special equipment. All site activities must also be considered as they may impact the selection of the drilling method.

3.3 WASTE GENERATION

Drilling operations typically generate significant volumes of waste that must be handled, stored, and eventually disposed of. This is of particular concern when drilling into contaminated or hazardous materials. The type and volume of wastes generated during drilling differs for different drilling methods. The different handling and disposal requirements of drilling wastes can greatly affect project costs. The different drilling methods can also require vastly different volumes of groundwater be removed to fully develop the well.

DISCLAIMER
This SOP provided general guidance for TIMET contractors and subcontractors for technical issues addressed during environmental site investigation and remediation activities. It is noted, however, that each site and project is unique and these guidelines are not a substitute for common sense and good management practices based on professional training and experience. In addition, individual contract terms may affect the implementation of this SOP. TIMET contractors reserve the unrestricted right to change, modify or not apply these guidelines in their sole, complete, and unrestricted discretion to meet certain circumstances, contractual requirements, site conditions, or job requirements.

1.0 INTRODUCTION

The objective of logging a borehole is to document the details of the soil and rock recovered from the borehole. These details include soil type, color, grain size variation, grain characteristics, staining, odor, moisture content, plasticity, blowcounts, soil sample interval, soil recovery, and sample numbers. These data are used to reconstruct the borehole's stratigraphy, which can then be correlated with similar data from other boreholes in the region to produce geological and hydrogeological cross sections.

1.1 PURPOSE

The purpose of this Standard Operating Procedure (SOP) is to describe the methods and procedures for documenting and obtaining information from a borehole.

1.2 SCOPE

This SOP applies to boreholes installed during environmental investigations. Preprinted borehole log forms are available, and personnel involved in borehole logging will use the form to document field activities. Attachment A contains the sample field borehole log form.

1.3 DEFINITIONS

Definitions of terms that relate to borehole logging are presented below. Definitions of soil types are taken from the American Society for Testing and Materials (ASTM 1985)[1].

1.3.1 Grain Sizes

Unified Soils Classification System (USCS) grain sizes are based on U.S. standard sieve sizes, which are named as follows:

- Standard sieves with larger openings are named according to the size of the openings in the sieve mesh. For example, a "3-inch" sieve contains openings that are 3 inches square.

- Standard sieves with smaller openings are given numbered designations that indicate the number of openings per inch. For example, a "No. 4" sieve contains 4 openings per inch.

The following grain size definitions are paraphrased from ASTM Standard D2488-00. Field personnel should familiarize themselves with the grain size definitions and refer to the field guide (Figure 1) as a reference.

Boulders: Particles of rock that will not pass a 12-inch (300-mm) square opening

Cobbles: Particles of rock that will pass a 12-inch (300-mm) square opening and be retained on a 3-inch (75-mm) sieve

[1] ASTM, 2000, Standard D2488-00 Standard Practice for Description and Identification of Soils (Visual-Manual Procedure).

Gravel: Particles of rock that will pass a 3-inch (75-mm) sieve and be retained on a No. 4 (4.75-mm) sieve with the following subdivisions:

- Coarse gravel passes a 3-inch (75-mm) sieve and is retained on a 3/4-inch (19-mm) sieve
- Fine gravel passes a 3/4-inch (19-mm) sieve and is retained on a No. 4 (4.75-mm) sieve

Sand: Particles of rock that will pass a No. 4 (0.19-inch or 4.75-mm) sieve and be retained on a No. 200 (0.003-inch or 75-µm) sieve with the following subdivisions:

- Coarse sand passes a No. 4 (0.19-inch or 4.75-mm) sieve and is retained on a No. 10 (0.08-inch or 2-mm) sieve
- Medium sand passes a No. 10 (0.08-inch or 2-mm) sieve and is retained on a No. 40 (0.017-inch or 425-µm) sieve
- Fine sand passes a No. 40 (0.017-inch or 425-µm) sieve and is retained on a No. 200 (0.003-inch or 75-µm) sieve

Silt: Soil passing a No. 200 (0.003-inch or 75-µm) sieve that is nonplastic or very slightly plastic and that exhibits little or no strength when air dried. Individual silt particles are not visible to the naked eye.

Clay: Soil passing a No. 200 (0.003 inch or 75-µm) sieve that can be made to exhibit plasticity within a range of water contents and that exhibits considerable strength when air-dried. Individual clay particles are not visible to the naked eye.

TERMS USED IN THIS REPORT FOR DISCRIBING SOILS ACCORDING TO THEIR TEXTURE OR GRAIN SIZE DISTRIBUTIONS ARE GENERALLY IN ACCORDANCE WITH THE UNIFIED SOIL CLASSIFICATION SYSTEM.

MAJOR DIVISIONS			GROUP SYMBOLS	TYPICAL NAMES
Coarse Grained Soil (More than half of material is larger than No. 200 seive)	Gravels (More than half of coarse fraction is larger than No. 4 seive size)	Clean Gravels (Little or no fines)	GW	Well-graded gravels, gravel-sand mixtures, little or no fines
			GP	Poorly-graded gravels, gravel-sand mixtures, little or no fines
		Gravels with fines (Appreciable amount of fines)	GM	Silty gravels, gravel-sand-silt mixtures
			GC	Clayey gravels, gravel-sand clay mixtures
	Sands (More than half of coarse fraction is smaller than No. 4 seive size)	Clean sands (Little or no fines)	SW	Well-graded sands, gravelly sands, little or no fines
			SP	Poorly grades sands, gravelly sands, little or no fines
		Sand with fines (Appreciable amount of fines)	SM	Silty sands, sand-silt mixtures
			SC	Clayey sands, sand-clay mixtures
Fine Grained Soils (More than half of material is smaller than No. 200 seive.)	Silts and Clays (Liquid Limit less than 50)		ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands, or clayey silts with slight plasticity
			CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
			OL	Organic silts and organic silty clays of low plasticity
	Silts and clays (Liquid limit greater than 50)		MH	Inorganic silts, diatomaceous or micaceous fine sandy or silty soils, elastic silts
			CH	Inorganic clays of high plasticity, fat clays
			OH	Organic clays of medium to high plasticity, organic silts
	Highly organic soil		Pt	Peat and other highly organic soils

TERMS DESCRIBING CONDITION CONSISTENCY AND HARDNESS

COARSE GRAINED SOILS (major portion retained on No. 200 seive);includes (1) clean gravels, (2) silty or clayey gravels and (3) silty, clayey or gravelly sands. Consistency is rated according to relative density, as determined by laboratory tests.

Descriptive Term	Realtive Density
Very loose	0 to 15%
Loose	15 to 40%
Medium dense	40 to 70%
Dense	70 to 85%
Very dense	85 to 100%

FINE GRAINED SOILS (major portion passing No. 200 seive): includes (1) inorganic and organic silts and clays, (2) gravelly, sandy or silty clays, and (3) clayey silts. Consistency is rated according to shearing strength as indicated by penetrometer readings or by direct shear tests.

Descriptive Term	Shear Strength (ksf)
Very soft	less than 0.25
Soft	0.25 to 0.50
Firm	0.50 to 1.00
Stiff	1.00 to 2.00
Very stiff	2.00 to 4.00
Hard	4.00 and higher

ROCK: Includes gravels, cobbles, rock, caliche and bedrock materials. Hardness is related to field identification procedures described below.

Descriptive Term	Field Identification Test
Soft	Can be dug by hand and crushed by fingers
Moderately Hard	Friable, can be gouged deeply with knife and will crumble readily under light hammer blow
Hard	Knife scratch leaves dust trace, will withstand a few hammer blows before breaking
Very Hard	Scratched with knife with difficulty, difficult to break with hammer blow

SOIL MOISTURE

From low to high soil moisture is indicated by:
- Dry
- Slightly Moist
- Moist
- Very moist
- Wet

SIZE PROPORTIONS

Designation	Percent by Weight
Trace	0 to 10
Little	10 to 20
Some	20 to 35
And	35 to 50

SAMPLER TYPES

Shelby	Converse
Split-Spoon	Bulk
Pitcher or Core	No Recovery

Figure 1 - Key to Soil Symbols and Terms

1.3.2 Physical Characteristics

The following physical characteristics are used in the USCS classification for fine-grained soils. A brief definition of each physical characteristic is presented below. Tables 1 through 4 present descriptions of field tests that may be performed to estimate these properties in a field sample. A determination of the type of fine-grained soil present in the sample can generally be made on the basis of plasticity, as described in Section 2.2.

Dry Strength : The ease with which a dry lump of soil crushes between the fingers (Table 1).

Dilatancy Reaction: The speed with which water appears in a moist pat of soil when shaking in the hand, and disappears while squeezing (Table 2).

Toughness: The strength of a soil, moistened near its plastic limit, when rolled into a 1/8-inch diameter thread (Table 3).

Plasticity: The extent to which a soil may be rolled into a 1/8-inch. thread, and re-rolled when drier than the plastic limit (Table 4).

Table 1. Criteria for Describing Dry Strength

Description	Criteria
None	The dry specimen crumbles into powder with mere pressure of handling.
Low	The dry specimen crumbles into powder with some finger pressure.
Medium	The dry specimen breaks into pieces or crumbles with considerable finger pressure.
High	The dry specimen cannot be broken with finger pressure. Specimen will break into pieces between thumb and a hard surface
Very High	The dry specimen cannot be broken between the thumb and a hard surface.

Table 2. Criteria for Describing Dilatancy Reaction

Description	Criteria
None	No visible change in the specimen.
Slow	Water appears slowly on the surface of the specimen during shaking and does not disappear or disappears slowly upon squeezing.
Rapid	Water appears quickly on the surface of the specimen during shaking and disappears quickly upon squeezing.

Table 3. Criteria for Describing Toughness

Description	Criteria
Low	Only slight pressure is required to roll the thread near the plastic limit. The thread and the lump are weak and soft.
Medium	Medium pressure is required to roll the thread to near the plastic limit. The thread and the lump have medium stiffness.
High	Considerable pressure is required to roll the thread to near the plastic limit. The thread and the lump have very high stiffness.

Table 4. Criteria for Describing Plasticity

Description	Criteria
Nonplastic	A 1/8-inch (3-mm) thread cannot be rolled at any water content.
Low	The thread can barely be rolled and the lump cannot be formed when drier than the plastic limit.
Medium	The thread is easy to roll and not much time is required to reach the plastic limit. The thread cannot be re-rolled after reaching the plastic limit. The lump crumbles when drier than the plastic limit.
High	It takes considerable time rolling and kneading to reach the plastic limit. The thread can be re-rolled several times after reaching the plastic limit. The lump can be formed without crumbling when drier than the plastic limit.

2.0 LOGGING A BOREHOLE

This SOP is based on the USCS and the American Society for Testing and Materials (ASTM) Standard D2488-00 Standard Practice for Description and Identification of Soils (Visual-Manual Procedure)[2]. The USCS classifies soils based on texture and liquid limits. The system consists of 15 soil groups, each identified by a two-letter symbol. The major divisions within the USCS (the first letter in each two-letter symbol) denote particle size: coarse-grained soils are sands (S) and gravels (G); fine-grained soils are silts (M) and clays (C). In coarse-grained soils, the second letter in the classification refers to the grading (sorting) of the soils. Thus (W) represents clean, well graded (poorly sorted) materials, while (P) represents clean, poorly graded (well sorted) materials. In fine-grained soils, the silts and clays are further subdivided in terms of liquid limits, with (L) indicating soils with low liquid limits and (H) representing soils with high liquid limits.

2.1 FIELD CLASSIFICATION

When naming soils, the proper USCS soil group name is given, followed by the group symbol. For clarity, it is recommended that the group symbol be placed in parentheses after the written soil group name. Soil identification using the visual-manual procedures is based on naming the portion of the soil sample that will pass a 3-inch (75-mm) sieve. Therefore, before classifying a soil, any particles larger than 3 inches (cobbles and boulders) should be removed, if possible. Estimate and note the percentage of cobbles and boulders.

Using the remaining soil, the next step is to estimate the percentages, by dry weight, of the gravel, sand, and fine fractions (particles passing a No. 200 sieve). The percentages are to be estimated to the closest 5 percent. In general, the soil is *fine-grained* (e.g., a silt or a clay) if it contains 50 percent or more fines, and *coarse-grained* (e.g., a sand or a gravel) if it contains less than 50 percent fines. If one of the components is present but estimated to be less than 5 percent, its presence is indicated by the term *trace*. For example, “trace of fines” would be added as additional information following the formal USCS soil description.

[2] ASTM, 2000, Standard D2488-00 Standard Practice for Description and Identification of Soils (Visual-Manual Procedure).

2.1.1 Procedure for Identifying Coarse-Grained Soils

Coarse-grained soil contains less than 50 percent fines. If it has been determined that the soil contains less than 50 percent fines, the soil is *gravel* if the percentage of gravel is estimated to be more than the percentage of sand. The soil is sand if the percentage of gravel is estimated to be equal to or less than the percentage of sand.

If the soil is predominantly sand or gravel but contains an estimated 15 percent or more of the other coarse-grained constituent, the words "with gravel" or "with sand" is added to the group name. For example: "gravel with sand (GP)." If the sample contains any cobbles or boulders, the words “with cobbles” or “with cobbles and boulders” are added to the group name. For example: "silty gravel with cobbles (GM)."

5 Percent or Less Fines
The soil is a “clean gravel” or “clean sand” if the percentage of fines is estimated to be 5 percent or less. “Clean” is not a formal USCS name, but rather a general descriptor for implying little to no fines. Clean sands and gravels are given the USCS designation as either *well-graded* or *poorly-graded*, as described below.

Identify the soil as *well-graded gravel* (GW) or as *well-graded sand* (SW) if it has a wide range of particle sizes and substantial amounts of the intermediate particle sizes. Identify the soil as *poorly-graded gravel* (GP) or as *poorly-graded sand* (SP) if it consists predominantly of one grain size (uniformly graded), or has a wide range of sizes with some intermediate sizes obviously missing (gap- or skip-graded).

Note: When using the USCS designation, keep in mind the difference between grading and sorting. The term grading is used to indicate the range of particles contained in the sample. For example, a poorly-graded sand containing predominantly one grain size would be considered well-sorted, and vice-versa. One notable exception to this general rule is a skip-graded (bimodally distributed) sample; a sand containing two distinct grain sizes would be considered both poorly-sorted and poorly-graded. The USCS uses only the *grading* descriptor in soil naming, not the sorting descriptor.

= 15 Percent Fines
The soil is *silty* or *clayey gravel* or *silty* or *clayey sand* if the percentage of fines is estimated to be 15 percent or more. For example, identify the soil as *clayey gravel* (GC) or *clayey sand* (SC) if the fines are clayey. Identify the soil as *silty gravel* (GM) or *silty sand* (SM) if the fines are silty. The coarse grained descriptor "poorly-graded" or "well-graded" is not included in the soil name, but rather, should be included as additional information following the formal USCS soil description.

>5 Percent but <15 Percent Fines
If the soil is estimated to contain greater than 5 percent but less than 15 percent fines, give the soil a dual identification using two group symbols. The first group symbol corresponds to a clean gravel or sand (GW, GP, SW, SP) and the second symbol corresponds to a clayey/silty gravel or sand (GC, GM, SC, SM). The group name corresponds to the first group symbol, and include the words "poorly-graded" or "well-graded", plus the words "with clay" or "with silt" to indicate the character of the fines. For example, "poorly-graded gravel with silt (GP-GM)".

2.1.2 Procedure for Identifying Fine-Grained Soils

Fine-grained soil contains 50 percent or more fines. The USCS classifies inorganic fine-grained soils according to their degree of plasticity (no or low plasticity, indicated with an "L"; or high plasticity, indicated with an "H") and other physical characteristics (defined in Section 1.3.2 and Tables 1 through 4). As indicated in Section 1.3.2, the field tests used to determine dry strength, dilatancy, and toughness are generally too time consuming to be performed on a routine basis. Field personnel should be familiar with the definitions of the physical characteristics and the concepts of the field tests; however, field classifications will generally be based primarily on plasticity. If precise engineering properties are necessary for the project (i.e., construction, modeling, etc.), geotechnical samples should be collected for laboratory testing. The results of the laboratory tests should be compared to the field logging results. Soil classifications based on plasticity are as follows:

- Lean clay (CL) soil has medium to high dry strength, no or slow dilatancy, and medium toughness and plasticity.

- Fat clay (CH) soil has high to very high dry strength, no dilatancy, and high toughness and plasticity.

- Silt (ML) soil has no to low dry strength, slow to rapid dilatancy, and low toughness and plasticity, or is nonplastic.

- Elastic silt (MH) soil has low to medium dry strength, no to slow dilatancy, and low to medium toughness and plasticity. They will air dry more quickly than lean clay and have a smooth, silky feel when dry.

- Organic soil (OL or OH) soil contains enough organic particles to influence the soil properties. Organic soils usually have a dark brown to black color and may have an organic odor. Organic soils will often change color, from black to brown for example, when exposed to the air. Organic soils normally will not have a high toughness or plasticity.

2.1.3 Other Modifiers for Use With Fine-Grained Soils

15 percent to 25 percent coarse-grained material
If the soil is estimated to have 15 percent to 25 percent sand or gravel, or both, the words "with sand" or "with gravel" (whichever is predominant) is added to the group name. For example: "lean clay with sand (CL)" or "silt with gravel (ML)". If the percentage of sand is equal to the percentage of gravel, use "with sand."

=30 percent coarse-grained material
If the soil is estimated to have 30 percent or more sand or gravel, or both, the words "sandy" or "gravelly" is added to the group name. Add the word "sandy" if there appears to be the same or more sand than gravel. Add the word "gravelly" if there appears to be more gravel than sand. For example: "sandy silt (ML)", or "gravelly fat clay (CH)".

2.2 PROCEDURE FOR IDENTIFYING BORDERLINE SOILS

To indicate that the soil may fall into one of two possible basic groups, a borderline symbol may be used with the two symbols separated by a slash. For example, a soil containing an estimated 50 percent silt and 50 percent fine grained sand may be assigned a borderline symbol "SM/ML". Borderline symbols should not be used indiscriminately. Every effort should be made to first place the soil into a single group and then to estimate percentages following the USCS soil description.

2.3 DESCRIPTIVE INFORMATION FOR SOILS

After the soil name and symbol are assigned, the soil color, consistency/density, and moisture content is to be described in that order. Other information is presented later in the description, as applicable.

2.3.1 Color

Color is an important property in identifying organic soils, and may also be useful in identifying materials of similar geologic or depositional origin in a given location. The Munsell Soil Color Charts should be used, if possible. When using the Munsell Soil Color Charts, a general color, such as brown, gray, red is first assigned to the soils. Then go to the correct area in the charts and assign the applicable color name and Munsell symbol. The ability to detect minor color differences varies among people, and the chance of finding a perfect color match in the charts is rare. Keeping this in mind should help field personnel avoid spending unnecessary time and confusion going through the chart pages. In addition, attempting to describe detail beyond the reasonable accuracy of field observations could lead to making poorer soil descriptions than by simply expressing the dominant colors[3]. If the color charts are not being used or are unavailable, again attempt to assign general colors to soils. Comparing a particular soil sample to samples from different locations in the borehole will help keep the eye "calibrated". For example, by holding two soils together, it may become evident that one is obviously greenish-brown, while another is reddish.

2.3.2 Consistency/Density

For intact fine-grained soil, describe consistency as very soft, soft, medium stiff, stiff, very stiff, or hard, based on the blows per foot using a 140 pound hammer dropped 30 inches (Table 5). If blow counts are not available, perform the field test described in Table 6 to determine consistency. For coarse-grained soils, describe density based on blows per foot as very loose, loose, medium dense, dense, and very dense (Table 5). If blow counts are not available, attempt to estimate the soil density by observation, since a practical field test is not available. Be sure to clearly indicate on the field boring log if blow counts could not be obtained.

[3] Munsell Soil Color Chart, 1992

Table 5. Density/Consistency Based on Blow Counts

Density (Sand and Gravel) Blows/ft [a]				Consistency (Silt and Clay) Blows/ ft [a]			
Term	1.4” ID	2.0” ID	2.5” ID	Term	1.4” ID	2.0” ID	2.5” ID
Very Loose	0 – 4	0 – 5	0 – 7	Very Soft	0 – 2	0 – 2	0 – 2
Loose	4 – 10	5 – 12	7 – 18	Soft	2 – 4	2 – 4	2 – 4
Medium Dense	10 – 29	12 – 37	18 – 51	Medium Stiff	4 – 8	4 – 9	4 – 9
Dense	29 – 47	37 – 60	51 – 86	Stiff	8 – 15	9 – 17	9 – 18
Very Dense	>47	>60	>86	Very Stiff	15 – 30	17 – 39	18 – 42
				Hard	30 – 60	39 – 78	42 – 85
				Very Hard	>60	>78	>85

[a] 140 lb. Hammer dropped 30 inches

Table 6. Criteria for Describing Consistency

Description	Criteria
Very Soft	Thumb will penetrate soil more than 1 inch (25 mm)
Soft	Thumb will penetrate soil about 1 inch (25 mm)
Firm	Thumb will indent soil about ¼ inch (6 mm)
Hard	Thumb will not indent soil but readily indented with thumbnail
Very Hard	Thumbnail will not indent soil

2.3.3 Moisture

Describe the moisture condition of the soil as dry (absence of moisture, dusty, dry to the touch), moist (damp but no visible water), or wet (visible free water, saturated).

2.3.4 Grain Size

Describe the maximum particle size found in the sample in accordance with the following information:

- Sand-size—describe as fine, medium, or coarse. (See Section 3.1.1 for sand size definitions.)
- Gravel-size—describe the diameter of the maximum particle size in inches.
- Cobble or boulder-size—describe the maximum dimension of the largest particle.

For gravel and sand components, describe the range of particle sizes within each component. For example, "about 20 percent fine to coarse gravel, about 40 percent fine to coarse sand".

2.3.5 Odor

Due to health and safety concerns, **NEVER** intentionally smell the soil. This could result in exposure to volatile contaminants that may be present in the soil. If, however, an odor is noticed, it should be described if organic or unusual (e.g., petroleum product or chemical). Soils containing a significant amount of organic material usually have a distinctive odor of decaying vegetation (sometimes a hydrogen sulfide [rotten egg] smell). Organic vapor readings from a photoionization detector (PID) or similar instrument should be noted on the field boring log (Note: see SOP-54 for additional information on PID principles and procedures.). The project-specific health and safety plan should then be consulted to determine the appropriate level of protection necessary to continue field work.

2.3.6 Cementation

Describe the cementation of intact coarse-grained soils as weak, moderate, or strong, in accordance with the following criteria:

- Weak—crumbles or breaks with handling or little finger pressure
- Moderate—crumbles or breaks with considerable finger pressure
- Strong—will not crumble or break with finger pressure

The presence of calcium carbonate may be confirmed on the basis of effervescence with dilute hydrochloric acid (HCl) if calcium carbonate or caliche is believed to be present in the soil.

2.3.7 Angularity

The angularity of the sand (coarse sizes only), gravel, cobbles, and boulders, as angular, subangular, subrounded, or rounded are described in accordance with the following criteria:

- Angular particles have sharp edges and relatively planar sides with unpolished surfaces.
- Subangular particles are similar to angular description but have rounded edges.
- Subrounded particles have nearly plane sides but have well-rounded corners and edges.
- Rounded particles have smoothly curved sides and no edges.

A range of angularity may be stated, such as "subrounded to rounded."

2.3.8 Structure

Describe the structure of intact soils in accordance with the criteria in Table 7.

Table 7. Criteria for Describing Structure

Description	Criteria
Stratified	Alternating layers of varying materials or color with layers at least 6 mm thick; note thickness
Laminated	Alternating layers of varying materials or color with the layers less than 6 mm thick; note thickness
Fissured	Breaks along definite planes of fracture with little resistance to fracturing
Slickensided	Fracture planes appear polished or glossy, sometimes striated
Blocky	Cohesive soil that can be broken down in small angular lumps that resist further breakdown
Lensed	Inclusion of small pockets of different soils, such as small lenses of sand scattered through a mass of clay; note thickness
Homogenous	Same color and appearance throughout

2.4 LITHOLOGY

Describe the lithology (rock or mineral type) of the sand, gravel, cobbles, and boulders, if possible. It may be difficult to determine the lithology of fine and medium-grained sand or particles that have undergone alteration.

2.5 ADDITIONAL COMMENTS

Additional comments may include the presence of roots or other vegetation, fossils or organic debris, staining, mottling, or oxidation; difficulty in drilling, and caving or sloughing of the borehole walls. Also, when drilling in an area known or suspected to contain imported fill material, every effort should be made to identify the contact between fill and native soils. If a soil is suspected to be fill, this should be clearly indicated on the log following the soil description. Stratigraphic units and their contacts should be noted wherever possible.

2.6 BEDROCK DESCRIPTIONS

If the soil boring penetrates bedrock, the boring log should indicate the rock type, color, weathering, fracturing, competency, mineralogy, age (if known), and any other miscellaneous information available. Definitions of these terms are not included in this SOP, because only a small percentage of drilling activities conducted by TIMET will penetrate bedrock. If bedrock drilling is planned, the field team leader, with the concurrence of the project manager, makes arrangements to provide the field team with appropriate definitions and indicate the types with information that should be collected.

2.2 BORING LOG

The boring log form (example shown in Attachment 1) will be utilized to document the drilling event. Information in the log heading should be complete and accurate. In addition to soil descriptions, the following information should be included, at a minimum:

- Boring or monitoring well number
- Project name and job number

- Borehole location
- Name of individual who logged the boring
- Name of boring log reviewer
- Drilling contractor
- Drill rig type and method of drilling (for example, "CME 75, hollow stem auger")
- Type of soil sampler (for example, Modified California, continuous core, etc.)
- Borehole diameter and drill bit type
- Overdrill diameter
- Time and date that drilling started and finished
- Time and date that the well was completed or the soil boring backfilled, as appropriate
- Method of borehole abandonment
- Sketch map of boring or well location with estimated distances to major site features such as property lines or buildings, and north arrow
- Soil sample information should include the depth interval that was sampled, the blow counts per 6 inches, the amount of soil recovered, and the portion submitted for analysis or testing, if any. The sample identification number may also be noted on the log.

The degree to which soil samples are collected during a field effort depends on the overall scope and purpose of the investigation, which should be clearly defined before the field effort commences. Additional soil samples may need to be collected if, for example, soils are very heterogeneous or unexpected conditions such as perched water zones or zones of contamination are encountered. If groundwater is encountered during drilling, the depth to water and the time and date of the observation should be recorded. If the first water encountered is a perched zone, the depth, time, and date that any additional groundwater zones are encountered should also be recorded. Depth to water after drilling, the measuring point, and the date and time of the measurement(s) must be noted. Additional measurements of depth to groundwater, including depth and time, may be beneficial.

If a monitoring well is installed, the construction details such as casing material type, screen length and slot size should be noted on the boring log. The annulus fill material (sand pack, bentonite, grout, etc.) should also be recorded. If the soil boring is abandoned, the backfill material used (e.g., grout, bentonite, etc.) and volume used, should be recorded on the boring log.

3.0 OTHER APPLICABLE SOPS

Several other TIMET SOPs contain information related to soil boring and logging activities. The following is a list of these SOPs:

SOP-4	Sample Management and Shipping
SOP-7	Field Documentation
SOP-50	Soil Sampling
SOP-51	Drilling Methods
SOP-100	Monitoring Well Design and Installation

DISCLAIMER
This SOP provided general guidance for TIMET contractors and subcontractors for technical issues addressed during environmental site investigation and remediation activities. It is noted, however, that each site and project is unique and these guidelines are not a substitute for common sense and good management practices based on professional training and experience. In addition, individual contract terms may affect the implementation of this SOP. TIMET contractors reserve the unrestricted right to change, modify or not apply these guidelines in their sole, complete, and unrestricted discretion to meet certain circumstances, contractual requirements, site conditions, or job requirements.

BOREHOLE LOG

Boring ID:		
Monitoring Well ID:		
Project Number:	Project Name:	
Client: **TITANIUM METALS CORPORATION**		
Site: **TIMET Plant Site**		
Borehole Location:		
Logged By:		
Reviewed By:	Review Date:	
Drilling Contractor:		
Drill Rig Type/Method:		
Sampler Type:		
Borehole Diameter (inches):		feet bgs
Overdrilled Diameter (inches):	to:	feet bgs
Drill Start Date:	Drill Start Time:	
Drill Finish Date:	Drill Finish Time:	
Total Borehole Depth (feet bgs):		
Soil Boring Backfill Date:	Soil Boring Backfill Time:	
Ground Surface Reference Elevation (feet msl):		
Depth to Target Zone (feet bgs):	Date:	Time:
Depth to Other Water-Bearing Zones (feet bgs):		
Depth to Water After Drilling (feet bgs):		
Well Completion Date:	Well Completion Time:	
Screen Interval (feet bgs):	Total Well Depth (feet bgs):	
Well Diameter (inches):	Well Casing Material:	
Static Water Level After Well Installation (feet bgs):		

BOREHOLE LOCATION MAP

N

NOTES/REMARKS

CB= Core Barrel
SS= Split spoon
BT= Brass Tubes

Drilled

TIMET Plant Site **DATE:**
LOGGED BY:

BORING ID: **MW ID:**

Sampler Type/ Interval	Time	Recovered/Driven (in./in.)	Pocket Penetrometer (tons/ft^2)	PID Reading (ppm)	Depth (feet bgs)	Lithologic Unit	USCS Type/Designation	Soil Description
					0			
					1			
					2			
					3			
					4			
					5			
					6			
					7			
					8			
					9			
					10			
					11			
					12			
					13			
					14			
					15			
					16			
					17			
					18			
					19			
					20			

TIMET Plant Site **DATE:**

LOGGED BY:

BORING ID: **MW ID:**

Sampler Type/ Interval	Time	Recovered/Driven (in./in.)	Pocket Penetrometer (tons/ft^2)	PID Reading (ppm)	Depth (feet bgs)	Lithologic Unit	USCS Type/Designation	Soil Description
					20			
					21			
					22			
					23			
					24			
					25			
					26			
					27			
					28			
					29			
					30			
					31			
					32			
					33			
					34			
					35			
					36			
					37			
					38			
					39			
					40			

TIMET Plant Site

DATE:

LOGGED BY:

BORING ID: **MW ID:**

Sampler Type/ Interval	Time	Recovered/Driven (in./in.)	Pocket Penetrometer ($tons/ft^2$)	PID Reading (ppm)	Depth (feet bgs)	Lithologic Unit	USCS Type/Designation	Soil Description
					40			
					41			
					42			
					43			
					44			
					45			
					46			
					47			
					48			
					49			
					50			
					51			
					52			
					53			
					54			
					55			
					56			
					57			
					58			
					59			
					60			

TIMET Plant Site

DATE:

LOGGED BY:

BORING ID: **MW ID:**

Sampler Type/ Interval	Time	Recovered/Driven (in./in.)	Physical Analysis	PID Reading (ppm)	Depth (feet bgs)	Lithologic Unit	USCS Type/Designation	Soil Description
					60			
					61			
					62			
					63			
					64			
					65			
					66			
					67			
					68			
					69			
					70			
					71			
					72			
					73			
					74			
					75			
					76			
					77			
					78			
					79			
					80			

TIMET Plant Site

DATE:

LOGGED BY:

BORING ID: **MW ID:**

Sampler Type/ Interval	Time	Recovered/Driven (in./in.)	Physical Analysis	PID Reading (ppm)	Depth (feet bgs)	Lithologic Unit	USCS Type/Designation	Soil Description
					80			
					81			
					82			
					83			
					84			
					85			
					86			
					87			
					88			
					89			
					90			
					91			
					92			
					93			
					94			
					95			
					96			
					97			
					98			
					99			
					100			

TIMET Plant Site **DATE:**

LOGGED BY:

BORING ID: **MW ID:**

Sampler Type/ Interval	Time	Recovered/Driven (in./in.)	Physical Analysis	PID Reading (ppm)	Depth (feet bgs)	Lithologic Unit	USCS Type/Designation	Soil Description
					100			
					101			
					102			
					103			
					104			
					105			
					106			
					107			
					108			
					109			
					110			
					111			
					112			
					113			
					114			
					115			
					116			
					117			
					118			
					119			
					120			

TIMET Plant Site

DATE:
LOGGED BY:

BORING ID: **MW ID:**

Sampler Type/ Interval	Time	Recovered/Driven (in./in.)	Physical Analysis	PID Reading (ppm)	Depth (feet bgs)	Lithologic Unit	USCS Type/Designation	Soil Description
					120			
					121			
					122			
					123			
					124			
					125			
					126			
					127			
					128			
					129			
					130			
					131			
					132			
					133			
					134			
					135			
					136			
					137			
					138			
					139			
					140			

TIMET Plant Site

DATE:

LOGGED BY:

BORING ID: MW ID:

Sampler Type/ Interval	Time	Recovered/Driven (in./in.)	Physical Analysis	PID Reading (ppm)	Depth (feet bgs)	Lithologic Unit	USCS Type/Designation	Soil Description
					140			
					141			
					142			
					143			
					144			
					145			
					146			
					147			
					148			
					149			
					150			
					151			
					152			
					153			
					154			
					155			
					156			
					157			
					158			
					159			
					160			

TIMET Plant Site

DATE:
LOGGED BY:

BORING ID: **MW ID:**

Sampler Type/ Interval	Time	Recovered/Driven (in./in.)	Physical Analysis	PID Reading (ppm)	Depth (feet bgs)	Lithologic Unit	USCS Type/Designation	Soil Description
					160			
					161			
					162			
					163			
					164			
					165			
					166			
					167			
					168			
					169			
					170			
					171			
					172			
					173			
					174			
					175			
					176			
					177			
					178			
					179			
					180			

TIMET Plant Site

DATE:

LOGGED BY:

BORING ID: **MW ID:**

Sampler Type/ Interval	Time	Recovered/Driven (in./in.)	Physical Analysis	PID Reading (ppm)	Depth (feet bgs)	Lithologic Unit	USCS Type/Designation	Soil Description
					180			
					181			
					182			
					183			
					184			
					185			
					186			
					187			
					188			
					189			
					190			
					191			
					192			
					193			
					194			
					195			
					196			
					197			
					198			
					199			
					200			

TIMET Plant Site

DATE:

LOGGED BY:

BORING ID: **MW ID:**

Sampler Type/ Interval	Time	Recovered/Driven (in./in.)	Physical Analysis	PID Reading (ppm)	Depth (feet bgs)	Lithologic Unit	USCS Type/Designation	Soil Description
					200			
					201			
					202			
					203			
					204			
					205			
					206			
					207			
					208			
					209			
					210			
					211			
					212			
					213			
					214			
					215			
					216			
					217			
					218			
					219			
					220			

TIMET Plant Site

DATE:

LOGGED BY:

BORING ID: **MW ID:**

Sampler Type/ Interval	Time	Recovered/Driven (in./in.)	Physical Analysis	PID Reading (ppm)	Depth (feet bgs)	Lithologic Unit	USCS Type/Designation	Soil Description
					220			
					221			
					222			
					223			
					224			
					225			
					226			
					227			
					228			
					229			
					230			
					231			
					232			
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					234			
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					236			
					237			
					238			
					239			
					240			

1.0 INTRODUCTION

In 1997, the U.S. Environmental Protection Agency (EPA) issued Update III to SW-846, "Test Methods for Evaluating Solid Waste." As part of this update, Method 5035, "Closed – System Purge-and-Trap and Extraction for Volatile Organics in Soil and Waste Samples," was issued, necessitating the update of field collection procedures for VOC analyses. In this method, a hermetically sealed sampling vial is used to capture the soil matrix and effectively reduce the volatilization of compounds present in the matrix. This method is recognized for use in Resource Conservation and Recovery Act (RCRA) compliance testing, and Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) or "Superfund" sites. Method 5035 was again revised in July 2002 to Method 5035A.

In accordance with Method 5035A, the new "low-level" method for analyzing VOCs is performed by vapor partitioning using heated purge-and-trap; the "high-level" method is performed using methanol extraction. From an analytical perspective, the low-level method is still a direct analysis method by vapor partitioning and the high-level method still involves solvent extraction followed by a vapor-partitioning analysis technique. The revised methods predominantly differ with respect to the manner in which solid samples are collected and prepared for analysis.

The EPA has provided two protocols for implementation of SW-846 Method 5035A to improve the integrity of soil samples to be analyzed for VOCs from collection through transportation to analysis. Protocol 1 employs EnCore™ samplers (or suitable hermetically sealed soil sampling devices) with no field weighing or preservation. Protocol 2 requires field weighing and several alternatives for field preservation, including methanol and sodium bisulfate. Prior to selection of Protocol 2 at any facility, a trial collection should be undertaken to determine if sodium bisulfate reacts with the sample matrix; thereby creating a situation where loss of volatile compounds may occur.

1.1 PURPOSE

The purpose of this Standard Operating Procedure (SOP) is determine whether a hermetically sealed soil sampling device is appropriate for a given project and, if so, how best to implement it. The most suitable sampling device will also be determined during the planning process for the sampling event. For convenience, the term "EnCore™" will represent whatever device is selected for use. Most available devices are very similar in design and use to the EnCore™. It is intended to guide the Project Manager (PM), Project Engineer (PE), Field Team Leader (FTL), Site Geologist and/or Rig Geologist in planning field work to meet project goals and in making field decisions.

The receipt, preparation, and analysis of the Encore™ samples by the laboratory is included in the laboratory SOPs for this method. The purpose of this SOP is to provide procedures for field personnel to follow in order to collect a representative sample that minimizes volatilization of compounds that may be found in the matrix.

1.2 SCOPE

This SOP covers field sampling procedures associated with implementation of Protocol 1. EnCore™ sample containers require less sample volume than capped sleeves or jars, require no field chemical preservation, and minimize biodegradation and escape of VOCs. Use of the EnCore™ samplers avoids Department of Transportation (DOT) shipment issues and personnel exposure hazards related to chemical preservatives. It also reduces the potential for error introduction by contamination or imprecise weighing in the field. This guideline provides a description of the principles of operation, applicability, and implementability of soil sampling using EnCore™ sampling tools.

1.3 DEFINITIONS

<u>EnCore™ sampler</u>: A disposable plastic soil coring device used for sampling, temporary storage, and shipment of soil samples for volatiles analyses (Figure 1a, 1b).

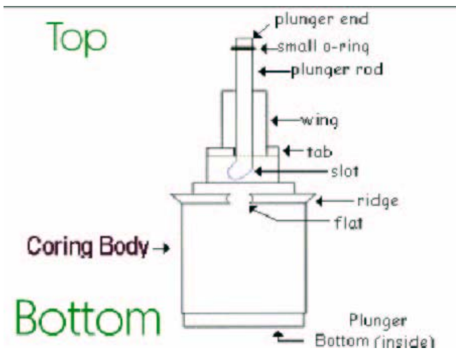


Figure 1a.
Schematic Drawing
EnCore™ Sampler

Figure 1b.
EnCore™ Samplers
5-gram and 25-gram

EnCore™ T-handle: A stainless steel handle that grips the core body of an EnCore™ sampler so it can be pushed into and filled with minimally disturbed soil (Figure 2).

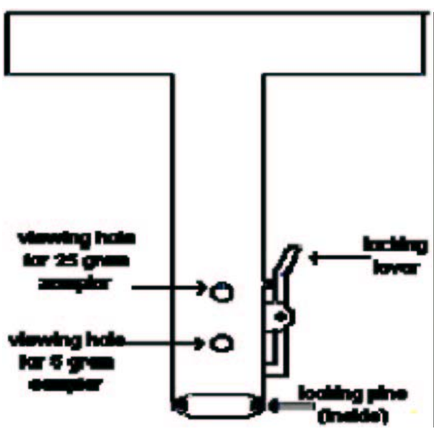


Figure 2a.
Schematic Drawing
EnCore™

Figure 2b.
T-Handle
EnCore™ T-Handle

Representative samples: Samples that represent all constituents at a certain depth interval. They do not represent undisturbed conditions. They are collected with a drive or push tube and/or an EnCore™sampler.

TPH-gasoline: Total petroleum hydrocarbons as gasoline.

VOCs: Volatile organic compounds.

1.4 REFERENCES

Koran, D., 1998. Memorandum for Record: Clarification for Sample Collection and Preparation Strategies for Volatile Organic Compounds (VOCs) in Solids

McGee, N., 1999. Memorandum: Regional Interim Policy for Determination of Volatile Organic Compound (VOC) Concentrations in Soil and Solid Matrices, United States Environmental Protection Agency, Region IX, San Francisco, California, 7 pp.

Nebelsick, J., 1998. USACE Sample Collection and Preparation Strategies for Volatile Organic Compounds in Solids, United States Army Corps of Engineers, 22 pp.

Turiff, D., and Klopp, C., 1994. Studies of Sampling, Storage and Analysis of Soils Contaminated with Gasoline and Diesel in Various Authors, 1998. Soil Sampling for Volatile Organics: an overview of regulatory changes that minimize volatilization and biodegradation, Berkeley, California, proceedings.

Turiff, D., and Reitmeyer, C., 1998. Validation of Holding Times for the EnCore Sampler™, En Novative Technologies, Inc., Green Bay, Wisconsin, 35 pp.

U.S. Environmental Protection Agency (USEPA), 1987. A Compendium of Superfund Field Operations Methods, EPA/540/p-87/001

USACE, 1998a. USACE Sample Collection and Preparation Strategies for Volatile Organic Compounds in Solids. July. USEPA, 1998b.

Clarification Regarding Use of SW-846 Methods, Memorandum from Elizabeth Cotsworth to RCRA Senior Policy Analysts, Attachment 1. August.

2.0 METHODOLOGY

To minimize VOC losses, the sample collection and preparation procedures were dramatically modified for both low-level and high-level methods. Using Protocol 2 (field preservation), field personnel transfer samples immediately from the sampling tool into pre-weighed vials containing chemical preservatives (e.g., sodium bisulfate solution or methanol). The vials are weighed in the field before use and are subsequently re-weighed after the sample aliquots are added to obtain the net sample weights. Alternatively, to avoid weighing and preserving the samples in the field, samples for both the low-level and high-level methods may be collected and subsequently stored at 4°C without chemical preservation, for a maximum of 48 hours, using the EnCore™ sampler. Experiments with several different soil types, several time and temperature combinations, and several volatile analytes have led to the following generalizations: (1) VOC concentrations decrease over time after sample collection, (2) freezing (-12° C) soil samples improves accuracy, and (3) variations in compound stability are more dependent on soil type and analytes than on storage conditions and time. If proper guidelines are followed, analytical results of samples collected in EnCore™ samplers closely resemble those of samples preserved in the field. These experiments showed VOCs remain stable for up to 14 days when frozen to -12°C in EnCore™ samplers. However, Method 5035A specifies a maximum 48-hour holding time between collection and extraction. Additionally, samples of calcareous soils that effervesce on contact with sodium bisulfate preservation solution must be collected in a device such as the EnCore™ sampler. Disadvantages to the field preservation protocol include the DOT shipping regulations governing the preservatives, as well as the health and safety hazards these chemicals pose to field staff. Also, making sure sample containers are appropriately preserved, labeled, dry, and clean for weighing twice provides many opportunities for error introduction in the field. Acid preservatives will react with any carbonates in soil, rendering volatiles analyses results inaccurate. Field preservation also presents more opportunities for ambient air contamination. Protocol 2 (EnCore™ sampling) costs to ship preservatives and to provide staff familiar with laboratory procedures for the increased field time (up to 50%) required for weighing and preservation are significantly greater than the costs of the EnCore™ samplers and T-handles.

Set aside the appropriate number and sizes of EnCore™ samplers and other containers required for each planned sample in advance to make sure all aliquots are collected. Take into consideration the need for additional samplers for quality control (QC) samples. If possible, complete the small sample labels (attached by perforated paper to the EnCore™ sampler pouches) with the appropriate sample numbers in advance, to minimize delays and confusion during drilling and sampling. Other labels, such as those to be affixed to the sample pouches, should also be completed as fully as possible in advance. Generic labels already attached to the pouches can be used if necessary. Immediately after sample collection, place all EnCore™ devices containing soil samples on ice. Plan to do all paperwork during periods when soil to be sampled is not exposed to ambient air. Lithologic logging should be done after samples are collected, labeled, and packed in ice, for a given interval.

2.1 SAMPLE COLLECTION

Attach an EnCore™ sampler (either size) to the T-handle, first making sure the plunger can move freely inside the coring body, then placing the plunger bottom flush with the open end of the coring body. Insert the plunger end of the sampler into the open end of the T-handle, depressing its locking lever and aligning the locking pins with the slots on the coring body. Release the lever and rotate the coring body to lock the pins in the slots. Make sure the T-handle and sampler are locked together (Figure 3). Check the O-ring inside the sampler's cap. If it is displaced, the cap is defective and another cap must be used. Keep the cap within reach in a clean, dry area.

Figure 3.
T-Handle and Sampler in Locked Position

As soon as the split-spoon sampler, or other down-hole sampling tool, is withdrawn from the borehole, open it and quickly select the interval to be sampled. Collect aliquots for VOCs first, then TPH-gasoline, if required. Aliquots for volatiles analyses should be collected before those for any non-volatiles analyses. To collect soil from a sleeve, place the sleeve upright with a Teflon™ sheet between it and the table. If more than a few seconds have elapsed since the sleeve was exposed to ambient air, scrape the uppermost soil out of the sleeve with a knife and discard it. Press the coring body, with the T-handle upward, into freshly exposed (but minimally disturbed) soil inside the sleeve

(Figure 4a). Depending on the lithology of the soil being sampled, a few hundred pounds of pressure and several minutes may be required to fill the sampler. As the sampler is pushed into the soil, the soil pushes the plunger upward. The O-ring on the plunger rod will align with the center of the appropriate viewing hole on the T-handle when the sampler is full (Figure 1a, Figure 4b). If the sampler is the 5-gram size, the center of the lower viewing hole (T-handle upward, coring body down) is the full level. The center of the upper viewing hole represents the full level for the 25-gram sampler.

Figure 4a.

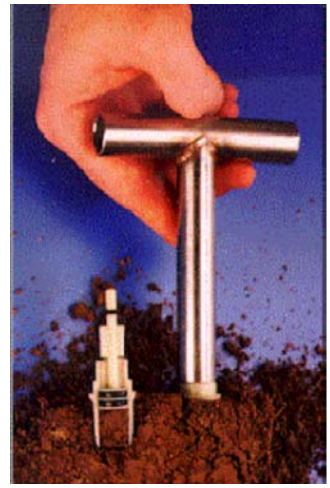


Figure 4b.
Inserting EnCore™
Sampler into Soil Soil Core

To collect soil from a bucket, select the least-disturbed looking soil in the bucket, and push the sampler into it, following the same procedures as above.

To collect soil directly from the ground surface, remove the uppermost soil with a knife to expose undisturbed soil, then follow the same procedures as above. Also, place some of the soil from each sampled interval into a plastic bag and seal it, leaving little head space. Make a small opening in the bag and insert the PID. Record the reading with the corresponding sample information on the chain-of-custody form.

2.2 SAMPLER CAPPING

When the sampler is full, pull the T-handle to withdraw the sampler from the sleeve and quickly remove excess soil from the end and outside of the coring body with a clean, dry paper towel. Cap the sampler, while it is still attached to the T-handle, by sliding the cap's locking arms through the flat areas of the sampler's ridges (Figure 5a). Then twist the cap so the grooves in the locking arms grip the ridges.

Figure 5a.
Sample Capping Procedure

Figure 5b.
Capped Sampler

Capping the sampler properly is important to ensure a tight seal to prevent escape of VOCs, but it is often difficult to fit the caps correctly onto the samplers. To make this easier, before capping, make sure the surface of the sampled soil is flat and does not extend beyond the open end of the sampler. Also, make sure the outside of the open edge of the coring body is clean. If, after these measures are taken, the cap is still uneven, firmly strike the table with the capped end of the sampler until the grooves on both locking arms are completely over the ridges. Depress the locking lever on the T-handle and rotate it slightly to release the sampler (Figure 5b).

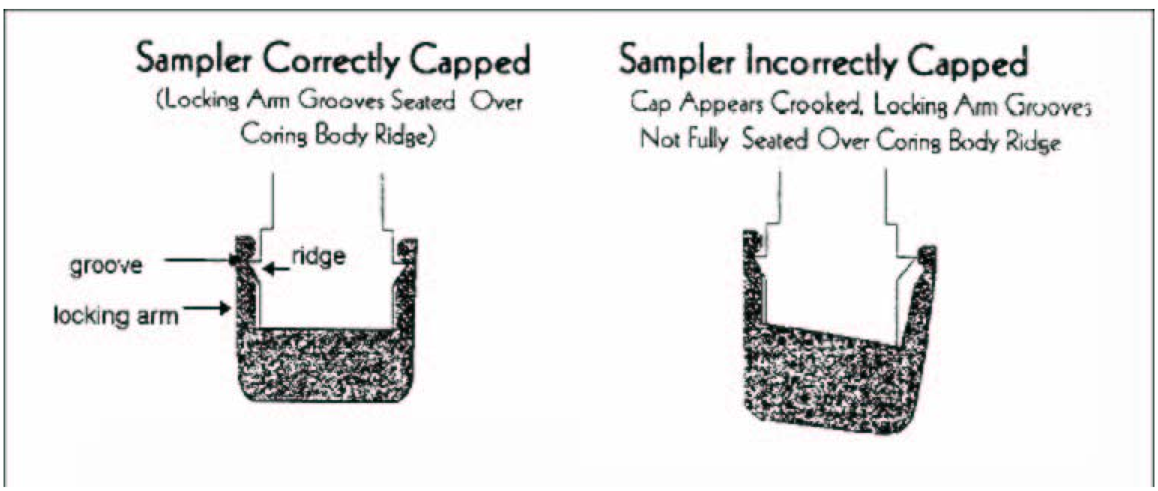


Figure 6.
Sample Correctly Capped and Incorrectly Capped

2.3 SAMPLER LOCKING

Slide the extended plunger rod through the holes in one arm of the T-handle until the wings of the plunger rod fit into the holes. Use the T-handle as a wrench to rotate the extended plunger rod until its wings rest firmly against the tabs. This keeps the plunger from pushing the soil against the cap during storage and shipment. To continue sampling, expose a fresh soil surface on either end of the same or an adjacent sleeve, and repeat the procedure above, until all required aliquots for that sample are obtained. If aliquots for other analyses are required, either cap unused sleeves or fill other sample containers as appropriate. If no other analyses are planned, collect an aliquot for percent moisture analysis.

2.4 LABELING

Tear the completed small sample label from the mylar pouch along the perforations, and attach it to the cap of the sampler. Place the labeled sampler inside the pouch and seal it. Attach a completed sample label to the outside of the pouch, making sure the labels correspond to each other. Make sure the pouch is sealed.

2.5 QUALITY CONTROL SAMPLES

Duplicate samples, usually collected at a rate of one per 10 normal environmental samples, require a second set of EnCore™ samplers to be filled. For example, if a normal sample requires one 25-gram and two 5-gram samplers for VOCs, and one 25-gram and two 5-gram samplers for TPH-gasoline, then its duplicate will also require four 5-gram and two 25-gram samplers to be filled. Every attempt should be made to fill these samplers from a co-located soil interval. Matrix spike/matrix spike duplicate (MS/MSD) samples, usually collected at a rate of one per 20 normal environmental samples, will require triple volume. The above-described sample would require filling 12 5-gram and six 25-gram samplers, if it were an MS/MSD sample. Again, all of these samplers should be filled from soil intervals as close together as possible. Other quality control samples, including trip blanks, ambient blanks, and equipment blanks, may be applicable and should be collected as required by the Generic Site-wide Sampling and Analysis Plan.

2.6 PACKING AND SHIPPING

To avoid confusion, keep all filled, capped, locked, and labeled EnCore™ samplers (in their respective sealed pouches) for an individual sample together in a sealed plastic bag. Place each bag of EnCore™ pouches, along with other sample containers, in an ice-cooled chest (4° C). Use wet ice in double Ziploc™ bags (to prevent leakage) or dry ice, depending on site specific work plans and shipping requirements. Make sure the laboratory will receive and extract/preserve the samples within 48 hours of their collection.

DISCLAIMER
This SOP provided general guidance for TIMET contractors and subcontractors for technical issues addressed during environmental site investigation and remediation activities. It is noted, however, that each site and project is unique and these guidelines are not a substitute for common sense and good management practices based on professional training and experience. In addition, individual contract terms may affect the implementation of this SOP. TIMET contractors reserve the unrestricted right to change, modify or not apply these guidelines in their sole, complete, and unrestricted discretion to meet certain circumstances, contractual requirements, site conditions, or job requirements.

1.0 INTRODUCTION

Exposure to airborne organic contaminants can present a significant threat to worker health and safety. Identifying and quantifying these contaminants through air monitoring is essential for reconnaissance activities. Reliable measurements of airborne organic contaminants are necessary for selecting personal protective equipment, delineating areas where protection is needed, assessing the potential health effects of exposure, and determining the need for specific medical monitoring.

1.1 PURPOSE

The purpose of this Standard Operating Procedure (SOP) is to describe the procedure for using a photoionization detector (PID). The PID is a portable, nonspecific, vapor/gas detector employing the principle of photoionization to detect a variety of chemical compounds in air. A PID is capable of detecting and measuring real-time concentrations of many organic and inorganic vapors in air. A PID is similar to a flame ionization detector (FID) in application; however, the PID has somewhat broader capabilities in that it can detect certain inorganic vapors. Conversely, the PID is unable to respond to certain low molecular weight hydrocarbons, such as methane and ethane, which are readily detected by FID instruments.

1.2 SCOPE

This SOP provides guidelines for using a PID photoionization detector during environmental investigations.

1.3 DEFINITIONS

Flame Ionization: A process by which a sample gas is ionized with a flame allowing a count of carbon atoms to determine organic vapor concentration

Flame Ionization Detector (FID): A portable instrument used to detect, measure, and provide a direct reading of organic vapor concentrations in a gas sample that is ionized with a flame

Ionization Potential: The amount of energy needed to strip an electron from the orbit of its resident molecule, expressed in electron volts Organic Vapor: Airborne compounds composed of carbon, hydrogen, and other elements with chain or ring structures

Organic Vapor Analyzer (OVA): A portable instrument used to detect, measure, and provide a direct reading of the concentration of a variety of trace organic gases in the atmosphere through flame ionization

Photoionization: A process involving the absorption of ultraviolet light by a gaseous molecule, leading to ionization

Photoionization Detector (PID): A portable instrument used to detect, measure, and provide a direct reading of the concentrations of a variety of trace organic gases in the atmosphere through photoionization

1.4 REFERENCES

NIOSH/OSHA/USCG/EPA. 1985. “Occupational Safety and Health Guidance Manual for Hazardous Waste Site Activities.” U.S. Government Printing Office. Washington, DC.

2.0 GUIDELINES

The PID employs the principle of photoionization. The analyzer will respond to most vapors that have an ionization potential less than or equal to that supplied by the ionization source, which is an ultraviolet (UV) lamp. Photoionization occurs when an atom or molecule absorbs a photon of sufficient energy to release an electron and form a positive ion. This will occur when the ionization potential of the molecule in electron volts (eV) is less than the energy of the photon.

The sensor is housed in a probe and consists of a sealed ultraviolet light source that emits photons with an energy level high enough to ionize many trace organics, but not enough to ionize the major components of air (e.g., nitrogen, oxygen, carbon dioxide). The ionization chamber exposed to the light source contains a pair of electrodes, one a bias electrode, and the second the collector electrode. When a positive potential is applied to the bias electrode, an electro-magnetic field is created in the chamber. Ions formed by the adsorption of photons are driven to the collector electrode. The current produced is then measured and the corresponding concentration displayed on a meter, directly, in units above background.

Several probes are available for the PID, each having a different eV lamp and a different ionization potential. The selection of the appropriate probe is essential in obtaining useful field results. Though it can be calibrated to a particular compound, the instrument cannot distinguish between detectable compounds in a mixture of gases and, therefore, indicates an integrated response to the mixture. Three probes, each containing a different UV light source, are available for use with the PID instrument are 9.5, 10.2, and 11.7 eV. All three detect many aromatic and large molecular hydrocarbons. The 10.2 eV and 11.7 eV probes, in addition, detect some smaller organic molecules and some halogenated hydrocarbons. The 10.2 eV probe is the most useful for environmental response work, as it is more durable than the 11.7 eV probe and detects more compounds than the 9.5 eV probe. Gases with ionization potentials near to or less than that of the lamp will be ionized. These gases will thus be detected and measured by the analyzer. Gases with ionization potentials higher than that of the lamp will not be detected. Ionization potentials for volatile site-related chemicals are given in Table 1. For the project a 11.7 eV probe will be utilized unless otherwise specified.

2.1 INTERFERENCES AND LIMITATIONS

The following identifies some of the potential interferences and limitations with the PID instrument:

1. The PID is a nonspecific total vapor detector. It cannot be used to identify unknown substances; it can only roughly quantify them.

2. Certain toxic gases and vapors, such as hydrogen cyanide, have high ionization potentials and cannot be detected with a PID.

3. It does not detect a compound if the probe used has a lower energy level than the compound's ionization potential, and response may change when gases are mixed.

4. Readings can be reported only relative to the calibration standard used.

5. Total concentrations are relative to the calibration gas used. Therefore, contaminant concentrations cannot be identified. Also, while the instrument scale reads 0 to 2,000 parts per million (ppm), response is linear to the calibration gas.

6. Electrical power lines or power transformers may cause interference with the Instrument and thus cause measurement errors. Static voltage sources such as power lines, radio transmissions, or transformers may also interfere with measurements.

7. High winds and high humidity will affect measurement readings. The PID instrument may become unusable under foggy or humid conditions. An indication of this is the needle dropping below zero, or a slow constant climb on the read-out dial.

8. The lamp window must be periodically cleaned to ensure ionization of the new compounds by the probe (i.e., new air contaminants).

9. This instrument is not to be exposed to precipitation (rain). The units are not designed for this service.

10. Do not use this instrument for head space analysis where liquids can inadvertently be drawn into the probe.

11. Transport of calibration gas cylinders by passenger and cargo aircraft must comply with International Air Transport Association (IATA) Dangerous Goods Regulations or the U.S. Code of Federal Regulations, 49 CFR Parts 100-177. A typical calibration gas included with a PID is isobutylene. It is classified as a non-flammable gas, UN #1556 and the proper shipping name is Compressed Gas. It must be shipped by cargo aircraft only.

2.2 CALIBRATION

There are two steps to the calibration: fresh air and a span calibration to a standard gas. See the operation manual for the specific model being used. Calibration events will be documented in a logbook. Documentation will include the date inspected, person responsible for calibrating the instrument, the instrument number, calibration results, calibration gas information (source, type, concentration).

2.3 FIELD OPERATION

1. Unpack the instrument carefully. Unclamp the fasteners on the instrument cover from the main readout assembly. Remove the inner lid from the instrument cover by pulling out the two one-quarter turn fasteners. Remove the probe, handle, and cable from the instrument cover. Attach the handle and probe extension to the probe.

2. Allow the temperature of the unit to equilibrate to its surrounding. This should take about 5 minutes.

3. All readings are to be recorded in the site logbook. Readings should be recorded, following background readings, as "units above background," not ppm.

4. As with any field instrument, accurate results depend on the operator being completely familiar with the operator's manual. The instructions in the operating manual should be followed explicitly in order to obtain accurate results.

5. Position the probe assembly close to the area to be monitored because the low sampling rate allows for only very localized readings. Under no circumstances should the probe tip assembly be immersed in fluid.

6. While taking care to prevent the PID from being exposed to excessive moisture, dirt, or contamination, monitor the work activity as specified in the site Health and Safety Plan. The PID survey should be conducted at a slow to moderate rate of speed and the intake assembly (the probe) slowly swept from side to side. There is a 3- to 5-second delay in read-out depending upon the instruments sensitivity to the contaminant.

7. During drilling activities, PID monitoring is performed at regular intervals downhole, at the headspace, and in the breathing zone. In addition, where elevated organic vapor levels are encountered, monitoring may be performed in the breathing zone during actual drilling. When the activity being monitored is other than drilling, readings should emphasize breathing zone conditions.

8. When the activity is completed or at the end of the day, carefully clean the outside of the PID with a damp disposable towel to remove any visible dirt.

2.4 POST OPERATION

1. Turn instrument to OFF.

2. Return the PID to a secure area and check the calibration before charging. Connect the instrument to charger and plug in the charger. The probe must be connected to the readout unit to ensure that the unit accepts a charge.

3. Complete logbook entries, verifying the accuracy of entries and signing/initialing all pages. Following completion of a series of "0" readings, verify the instrument is working.

4. Check the equipment, repair or replace damaged equipment, and charge the batteries.

2.5 MAINTENANCE

1. Perform routine calibration prior to each use and at the end of each day.

2. Factory calibrate yearly, when malfunctioning, when the span setting exceeds the maximum span setting for the probe in use, and after the UV light source has been replaced.

3. Clean the main readout assembly after each use. Thoroughly decontaminate the instrument at the completion of the project.

4. Recharge the battery daily.

5. Care should be taken when sampling over solids and liquids so that it is not drawn into the instrument.

DISCLAIMER
This SOP provided general guidance for TIMET contractors and subcontractors for technical issues addressed during environmental site investigation and remediation activities. It is noted, however, that each site and project is unique and these guidelines are not a substitute for common sense and good management practices based on professional training and experience. In addition, individual contract terms may affect the implementation of this SOP. TIMET contractors reserve the unrestricted right to change, modify or not apply these guidelines in their sole, complete, and unrestricted discretion to meet certain circumstances, contractual requirements, site conditions, or job requirements.

Table 1
Photoionization Potentials of Organic Compounds

Parameter of Interest	Analytical Method	Compound List	CAS Number	Ionization Potential (eV)
Ions	**EPA 300.0**	Bromide	24959-67-9	n.p.
		Bromine	7726-95-6	10.52
		Chlorate	14866-68-3	n.p.
		Chloride	16887-00-6	n.p.
		Chlorine	7782-50-5	11.48
		Chlorite	14998-27-7	n.p.
		Fluoride	16984-48-8	n.p.
		Nitrate (as N)	14797-55-8	n.p.
		Nitrite (as N)	14797-65-0	n.p.
		Orthophosphate	14265-44-2	n.p.
		Sulfate	14808-79-8	n.p.
	EPA 377.1	Sulfite	14265-45-3	n.p.
	EPA 314.0	Perchlorate	14797-73-0	n.p.
Dissolved Gases	**RSK 175**	Ethane	74-84-0	11.52
		Ethylene	74-85-1	10.51
		Methane	74-82-8	12.61
General Chemistry	**EPA 350.2**	Ammonia	7664-41-7	10.07
	EPA 335.1/335.2	Cyanide	57-12-5	13.6
	EPA 345.1	Iodine	7553-56-2	9.31
Aldehydes	**EPA 8315A**	Acetaldehyde	75-07-0	10.23
		Chloroacetaldehyde	107-20-0	10.61
		Dichloroacetaldehyde	79-02-7	10.5
		Formaldehyde	50-00-0	10.88
		Trichloroacetaldehyde	75-87-6	10.9
Volatile Organic Compounds	**EPA 8260B**	1,1,1,2-Tetrachloroethane	630-20-6	11.1
		1,1,1-Trichloroethane	71-55-6	11.25
		1,1,2,2-Tetrachloroethane	79-34-5	11.10
		1,1,2-Trichloroethane	79-00-5	11.0
		1,1-Dichloroethane	75-34-3	11.04
		1,1-Dichloroethene	75-35-4	9.81
		1,1-Dichloropropene	563-58-6	n.p.
		1,2,3-Trichlorobenzene	87-61-6	9.18
		1,2,3-Trichloropropane	96-18-4	n.p.
		1,2,4-Trichlorobenzene	120-82-1	9.04
		1,2,4-Trimethylbenzene	95-63-6	8.27
		1,2-Dichlorobenzene	95-50-1	9.06
		1,2-Dichloroethane	107-06-2	11.07
		1,2-Dichloropropane	78-87-5	10.8
		1,3,5-Trichlorobenzene	108-70-3	9.3
		1,3,5-Trimethylbenzene	108-67-8	8.4
		1,3-Dichlorobenzene	541-73-1	9.1
		1,3-Dichloropropene	542-75-6	n.p.

Table 1 (continued)
Photoionization Potentials of Organic Compounds

Parameter of Interest	Analytical Method	Compound List	CAS Number	Ionization Potential (eV)
Volatile Organic Compounds (continued)	**EPA 8260B**	1,3-Dichloropropane	142-28-9	10.89
		1,4-Dichlorobenzene	106-46-7	8.92
		2,2-Dichloropropane	594-20-7	n.p.
		2,2-Dimethylpentane	590-35-2	n.p.
		2,2,3-Trimethylbutane	464-06-2	n.p.
		2,3-Dimethylpentane	565-59-3	n.p.
		2,4-Dimethylpentane	108-08-7	n.p.
		2-Chlorotoluene	95-49-8	8.72
		2-Hexanone	591-78-6	9.35
		2-Methylhexane	591-76-4	n.p.
		2-Nitropropane	79-46-9	10.74
		3,3-Dimethylpentane	562-49-2	n.p.
		3-Ethylpentane	617-78-7	n.p.
		3-Methylhexane	589-34-4	n.p.
		4-Chlorotoluene	106-43-4	8.69
		4-Methyl-2-pentanone (MIBK)	108-10-1	9.3
		Acetone	67-64-1	9.7
		Acetonitrile	75-05-8	12.2
		Benzene	71-43-2	9.24
		Bromobenzene	108-86-1	9.0
		Bromodichloromethane	75-27-4	10.6
		Bromoform	75-25-2	10.5
		Bromomethane	74-83-9	10.54
		Carbon disulfide	75-15-0	10.07
		Carbon tetrachloride	56-23-5	11.47
		Chlorobenzene	108-90-7	9.07
		Chlorobromomethane	74-97-5	10.77
		Chloroethane	75-00-3	10.98
		Chloroform	67-66-3	11.37
		Chloromethane	74-87-3	11.26
		cis-1,2-Dichloroethene	156-59-2	9.66
		cis-1,3-Dichloropropene	10061-01-5	n.p.
		Cymene (Isopropyltoluene)	99-87-6	8.29
		Dibromochloroethane	73506-94-2	n.p.
		Dibromochloromethane	124-48-1	10.59
		Dibromochloropropane	96-12-8	n.p.
		Dibromomethane	74-95-3	10.41
		Dichloromethane (Methylene chloride)	75-09-2	11.33
		Dimethyldisulfide	624-92-0	7.4
		Ethanol	64-17-5	10.48
		Ethylbenzene	100-41-4	8.77
		Freon-11	75-69-4	11.68

Table 1 (continued)
Photoionization Potentials of Organic Compounds

Parameter of Interest	Analytical Method	Compound List	CAS Number	Ionization Potential (eV)
Volatile Organic Compounds (continued)	EPA 8260B	Freon-113	76-13-1	11.99
		Freon-12	75-71-8	12.26
		Heptane	142-82-5	9.93
		Isoheptane	31394-54-4	n.p.
		Isopropylbenzene	98-82-8	8.73
		m-Xylene	108-38-3	8.55
		Methyl ethyl ketone (2-Butanone)	78-93-3	9.52
		Methyl iodide	74-88-4	9.54
		MTBE (Methyl tert-butyl ether)	1634-04-4	9.24
		n-Butyl benzene	104-51-8	8.69
		n-Propylbenzene	103-65-1	8.71
		Nonanal	124-19-6	n.p.
		o-Xylene	95-47-6	8.56
		p-Xylene	106-42-3	8.44
		sec-Butylbenzene	135-98-8	8.68
		Styrene	100-42-5	8.46
		tert-Butyl benzene	98-06-6	8.68
		Tetrachloroethene	127-18-4	9.33
		Toluene	108-88-3	8.83
		trans-1,2-Dichloroethene	156-60-5	9.64
		trans-1,3-Dichloropropene	10061-02-6	n.p.
		Trichloroethene	79-01-6	9.46
		Vinyl acetate	108-05-4	9.2
		Vinyl chloride	75-01-4	9.99
		Tentatively Identified Compounds (TICs)	--	--
Semi-Volatile Organic Compounds	EPA 8270C	1,2,4,5-Tetrachlorobenzene	95-94-3	9
		1,4-Dioxane	123-91-1	9.19
		2-Methylnaphthalene	91-57-6	7.91
		Acenaphthene	83-32-9	7.75
		Acenaphthylene	208-96-8	8.12
		Acetophenone	98-86-2	9.28
		Aniline	62-53-3	7.72
		Anthracene	120-12-7	7.44
		Benzo(a)anthracene	56-55-3	7.45
		Benzo(a)pyrene	50-32-8	7.12
		Benzo(g,h,i)perylene	191-24-2	7.17
		Chrysene	218-01-9	7.6
		Dibenzo(a,h)anthracene	53-70-3	7.39
		Diphenyl sulfide	139-66-2	7.85
		Diphenyl sulfone	127-63-9	9.16
		Fluoranthene	206-44-0	7.9
		Fluorene	86-73-7	7.91

Table 1 (continued)
Photoionization Potentials of Organic Compounds

Parameter of Interest	Analytical Method	Compound List	CAS Number	Ionization Potential (eV)
Semi-Volatile Organic Compounds (continued)	**EPA 8270C**	Hexachlorobenzene	118-74-1	9
		m,p-Cresol	106-44-5	8.34
		Naphthalene	91-20-3	8.14
		Nitrobenzene	98-95-3	9.94
		o-Cresol	95-48-7	8.24
		Pentachlorobenzene	608-93-5	8.8
		Phenanthrene	85-01-8	7.89
		Phenol	108-95-2	8.49
		Pyrene	129-00-0	7.43
		Pyridine	110-86-1	9.26
		Thiophenol	108-98-5	8.3
		All other SVOCs	108-98-5	n.p.

Notes:
n.p. - not published.
Source: National Institute of Standards and Technology (NIST) Chemistry WebBook (http://webbook.nist.gov).

1.0 INTRODUCTION

Drilling is a common activity associated with all phases of environmental investigations. Drilling methods are most commonly used to collect site data during site investigations and remedial investigations, but are also used to install vapor extraction or water wells associated with remedial actions. For determining the most appropriate drilling method for site investigations, primary consideration must be given to obtaining information that is representative of existing conditions and the collection of samples that are valid for chemical analysis. The samples must not be contaminated or adversely affected by the drilling method.

Field investigations usually require invasive types of activities to gather information to evaluate the site. The investigation may require the analysis of soil and/or groundwater samples which would be accomplished by drilling a borehole. Many times the borehole is converted into a well for the evaluation of vapor or groundwater conditions over time.

1.1 PURPOSE

The purpose of this Standard Operating Procedure (SOP) is to provide the procedures for plugging and abandoning an environmental investigation borehole or monitoring well.

1.2 SCOPE

This SOP provides a description of the borehole abandonment procedures used during field investigations for typical boreholes. The project-specific sampling and analysis plans may have site-specific concerns which would require additional or adjustment to these procedures. This document focuses on methods and equipment that are readily available and typically applied. It is not intended to provide an all inclusive discussion of borehole abandonment methods.

1.3 DEFINITIONS

See attached NAC Chapter 534 rules.

1.4 REFERENCES

The following references are attached to this SOP. Nevada Administrative Code (NAC) prescribes plugging requirements by rule, and must be followed. NAC 534 §422 allows plugging of wells by exceptional method, and in the event a plugging regimen is developed using this provision, ASTM D5299-99(2005) shall be used as guidance.

NAC Chapter 534. General Requirements for Plugging of Wells.

ASTM D5299 Guide for Decommissioning of Ground-Water Wells, Vadose Zone Monitoring Devices, Boreholes, and Other Devices for Environmental Activities

2.0 WELL AND BOREHOLE ABANDONMENT

A borehole that will not be converted into a well (for example, soil borings, test holes, and/or pilot holes) will be properly plugged and abandoned in accordance NAC 534.4371.Wells that are abandoned shall be plugged in accordance NAC 534.420.

Under no circumstances, unless previously approved by the Nevada Division of Environmental Protection (NDEP), will the borings be backfilled with the soil removed during drilling and sampling operations. Proper abandonment techniques for monitoring and other types of wells are dependent on site-specific circumstances and state (NDEP) requirements. Abandonment techniques may include, but not be limited to, removal of the well casing (for example, by pulling or by drilling out) followed by backfilling with cement/bentonite grout. The NDEP will be contacted for specific requirements, and the abandonment methods will be described in site-specific planning documents.

NEVADA ADIMISTRATIVE CODE
CHAPTER 534 - UNDERGROUND WATER AND WELLS
Excerpted Sections Regarding Plugging and Abandonment

NAC 534.010 Definitions. (NRS 534.020, 534.110) As used in this chapter, unless the context otherwise requires, the words and terms defined in NAC 534.015 to 534.240, inclusive, have the meanings ascribed to them in those sections.

(Supplied in codification; A by St. Engineer, 1-9-90; 12-30-97)

NAC 534.015 "Abandon" defined. (NRS 534.020, 534.110) "Abandon" means to discontinue the use of a well or borehole or to leave the well or borehole in such a state of disrepair that to use it would be impracticable, may result in contamination of ground water or may otherwise pose a hazard to the health or safety of the general public.

(Added to NAC by St. Engineer, eff. 1-9-90; A 12-30-97)

NAC 534.020 "Annular space" defined. (NRS 534.020, 534.110) "Annular space" means the space between two cylindrical objects, one of which surrounds the other, such as the space between the walls of the well bore and the casing.

[St. Engineer, Drilling Wells Reg. § 1.01, eff. 5-19-81]—(NAC A 1-9-90; 12-30-97)

NAC 534.030 "Aquifer" defined. "Aquifer" has the meaning ascribed to it in NRS 534.0105.

[St. Engineer, Drilling Wells Reg. § 1.02, eff. 5-19-81]—(NAC A 1-9-90)

NAC 534.040 "Artesian well" defined. "Artesian well" has the meaning ascribed to it in NRS 534.012.

[St. Engineer, Drilling Wells Reg. § 1.03, eff. 5-19-81]—(NAC A 1-9-90)

NAC 534.042 "Bentonite grout" defined. (NRS 534.020, 534.110) "Bentonite grout" means a product that is specifically designed to seal and plug wells and boreholes and:

1. Consists of not more than 87.9 percent water and not less than 12.1 percent bentonite by weight of water;
2. Has the ability to gel;
3. Does not separate into water and solid materials after it gels;

4. Has hydraulic conductivity or permeability values of 10-7centimeters per second or less; and
5. Has a fluid weight of not less than 9 pounds per gallon.
(Added to NAC by St. Engineer, eff. 12-30-97)

NAC 534.043 "Blast hole" defined. (NRS 534.020, 534.110) "Blast hole" means a borehole that is drilled and, as soon as practicable, is loaded with explosives for mining purposes.
(Added to NAC by St. Engineer, eff. 12-30-97)

NAC 534.045 "Board" defined. "Board" means the statewide well drillers' advisory board.

(Added to NAC by St. Engineer, eff. 1-9-90)

NAC 534.047 "Borehole" defined. (NRS 534.020, 534.110) "Borehole" means a penetration in the ground that is deeper than the longest dimension of its opening at the surface and is made to obtain geologic, hydrologic, geophysical or geotechnical information, to obtain information relating to engineering or for any other purpose other than for use as a well.
(Added to NAC by St. Engineer, eff. 12-30-97)

NAC 534.048 "Bridge" defined. (NRS 534.020, 534.110) "Bridge" means an obstruction in the well bore or annular space of a borehole or well caused when the walls of the well bore collapse or when materials are jammed or wedged into the well bore or annular space.
(Added to NAC by St. Engineer, eff. 12-30-97)

NAC 534.050 "Casing" defined. "Casing" means the conduit required to prevent waste and contamination of the ground water and to hold the formation open during the construction or use of the well.
[St. Engineer, Drilling Wells Reg. § 1.04, eff. 5-19-81]—(NAC A 1-9-90)

NAC 534.060 "Cement grout" defined. "Cement grout" means a mixture of Portland Cement, sand and water which contains at least seven bags of cement per cubic yard and not more than 7 gallons of clean water for each bag of cement (1 cubic foot or 94 pounds).
[St. Engineer, Drilling Wells Reg. § 1.14, eff. 5-19-81]—(NAC A 1-9-90)

NAC 534.070 "Concrete grout" defined. "Concrete grout" means a mixture of Portland Cement, sand, 1/4-inch minus aggregate and water which contains at least five bags of cement per cubic yard of concrete and not more than 7 gallons of clean water per bag of cement (1 cubic foot or 94 pounds).
[St. Engineer, Drilling Wells Reg. § 1.13, eff. 5-19-81]—(NAC A 1-9-90)

NAC 534.080 "Conductor casing" defined. (NRS 534.020, 534.110) "Conductor casing" means the temporary or permanent casing used in the upper portion of the well bore to prevent collapse of the formation during the construction of the well or to conduct the gravel pack to the perforated or screened areas in the casing.
[St. Engineer, Drilling Wells Reg. § 1.05, eff. 5-19-81]—(NAC A 1-9-90; 12-30-97)

NAC 534.094 "Contaminant" defined. (NRS 534.020, 534.110) "Contaminant" means any chemical, mineral, live organism, organic material, radioactive material or heated or cooled water that may adversely affect the quality of ground water.
(Added to NAC by St. Engineer, eff. 12-30-97)

NAC 534.095 “Contamination” defined. (NRS 534.020, 534.110) “Contamination” means the impairment of water quality by the introduction of contaminants into the ground water.

(Added to NAC by St. Engineer, eff. 1-9-90; A 12-30-97)

NAC 534.100 “Division” defined. “Division” means the division of water resources of the state department of conservation and natural resources.

[St. Engineer, Drilling Wells Reg. § 1.07, eff. 5-19-81]

NAC 534.110 “Domestic use” defined. “Domestic use” has the meaning ascribed to it NRS 534.013.

[St. Engineer, Drilling Wells Reg. § 1.08, eff. 5-19-81]—(NAC A 1-9-90)

NAC 534.112 “Drill rig” defined. (NRS 534.020, 534.110) “Drill rig” means any power-driven percussion, rotary, boring, coring, digging, jetting or augering machine used in the construction of a well or borehole.

(Added to NAC by St. Engineer, eff. 12-30-97)

NAC 534.113 “Drive point well” defined. (NRS 534.020, 534.110) “Drive point well” means a temporary monitoring well constructed by driving a drive point attached to the end of a section of pipe into the ground for the purpose of obtaining geotechnical or environmental information. The term is synonymous with a push point well.

(Added to NAC by St. Engineer, eff. 1-9-90; A 12-30-97)

NAC 534.120 “Exploratory well” defined. (NRS 534.020, 534.110) “Exploratory well” means a well constructed pursuant to paragraph (a) of subsection 2 of NRS 534.050 to determine the availability of water or whether an aquifer is capable of transmitting water to a well.

[St. Engineer, Drilling Wells Reg. § 1.09, eff. 5-19-81]—(NAC A 1-9-90; 12-30-97)

NAC 534.140 “Ground water” defined. (NRS 534.020, 534.110) “Ground water” means water below the surface of the land that is in a zone of saturation.

[St. Engineer, Drilling Wells Reg. § 1.11, eff. 5-19-81]—(NAC A 12-30-97)

NAC 534.148 “Monitoring well” defined. (NRS 534.020, 534.110) “Monitoring well” means any well that is constructed to evaluate, observe or determine the quality, quantity, temperature, pressure or other characteristic of ground water or an aquifer. The term includes an observation well, piezometer, drive point well or vapor extraction well.

(Added to NAC by St. Engineer, eff. 12-30-97)

NAC 534.150 “Neat cement” defined. (NRS 534.020, 534.110) “Neat cement” means a mixture of:

1. Clean water and cement in a ratio of not more than 5.2 gallons of water per bag of Portland Cement (1 cubic foot or 94 pounds); or
2. Clean water, cement and sodium bentonite in a ratio of not more than 7.8 gallons of water per 3.76 pounds of sodium bentonite by dry weight and one bag of Portland Cement (1 cubic foot or 94 pounds).

   [St. Engineer, Drilling Wells Reg. § 1.12, eff. 5-19-81]—(NAC A 12-30-97)

NAC 534.160 “Nominal size” defined. “Nominal size” means the manufactured commercial designation of the diameter of a casing. An example would be casing with an outside diameter of 12 3/4 inches which may be nominally 12-inch casing by manufactured commercial designation.

[St. Engineer, Drilling Wells Reg. § 1.15, eff. 5-19-81]

NAC 534.165 “Observation well” defined. (NRS 534.020, 534.110) “Observation well” means a borehole in which a temporary casing has been set and which is used to observe, test and measure the elevation of the water table, the pressure variations within an aquifer and the movement of contaminants inside or outside a zone of saturation.

(Added to NAC by St. Engineer, eff. 12-30-97)

NAC 534.175 “Permit” defined. “Permit” means the written permission from the state engineer to appropriate public waters for a beneficial use from a surface or underground source, at a specific point of diversion, under limited circumstances.

(Added to NAC by St. Engineer, eff. 1-9-90)

NAC 534.179 “Piezometer” defined. (NRS 534.020, 534.110) “Piezometer” means a well that is constructed to measure water pressure or soil moisture tensions at one or more discrete intervals.

(Added to NAC by St. Engineer, eff. 12-30-97)

NAC 534.182 “Pitless adapter” defined. (NRS 534.020, 534.110) “Pitless adapter” means a commercially manufactured device designed for attachment to openings through the casing of a water well that permits water service pipes to pass through the wall or an extension of a casing and prevents the entry of contaminants into the well or water supply.

(Added to NAC by St. Engineer, eff. 1-9-90; A 12-30-97)

NAC 534.183 “Plug” defined. (NRS 534.020, 534.110) “Plug” means the procedure in which a well or borehole is sealed after it is abandoned.

(Added to NAC by St. Engineer, eff. 1-9-90; A 12-30-97)

NAC 534.185 “Public survey” defined. (NRS 534.020, 534.110) “Public survey” means the description of the location of land using the survey system of the United States Government and includes the 40-acre subdivision within a quarter-quarter section, quarter section, section, township and range.

(Added to NAC by St. Engineer, eff. 1-9-90; A 12-30-97)

NAC 534.188 “Reconditioning” defined. (NRS 534.020, 534.110) “Reconditioning” means the deepening, reaming, casing, recasing, perforating, reperforating, installing of liner pipe, packers and seals or any other significant change in the design or construction of a water well.

(Added to NAC by St. Engineer, eff. 1-9-90; A 12-30-97)

NAC 534.190 “Seal” defined. (NRS 534.020, 534.110) “Seal” means the watertight seal established in a borehole or the annular space between the well casings or a well casing and the well bore to prevent the inflow or vertical movement of surface water or shallow ground water, or to prevent the outflow or vertical movement of water under artesian pressures. The term includes a sanitary seal.

[St. Engineer, Drilling Wells Reg. § 1.19, eff. 5-19-81]—(NAC A 1-9-90; 12-30-97)

NAC 534.192 “Seismic shot hole” defined. (NRS 534.020, 534.110) “Seismic shot hole” means a borehole in which an explosion is detonated to assist studies of the geology of the earth.

(Added to NAC by St. Engineer, eff. 12-30-97)

NAC 534.194 “Sodium bentonite” defined. (NRS 534.020, 534.110) “Sodium bentonite” means a colloidal clay that:

1. Consists primarily of the mineral montmorillonite;
2. Has the ability to swell; and
3. May be mixed with water to form bentonite grout.
   (Added to NAC by St. Engineer, eff. 12-30-97)

NAC 534.195 “Static water level” defined. (NRS 534.020, 534.110) “Static water level” means the stabilized level or elevation of the surface of the water in a well or borehole that is not being pumped and is not affected by the pumping of other wells or boreholes.

(Added to NAC by St. Engineer, eff. 1-9-90; A 12-30-97)

NAC 534.205 “Vapor extraction well” defined. (NRS 534.020, 534.110) “Vapor extraction well” means any well constructed to remove vapors that may contaminate the ground water.

(Added to NAC by St. Engineer, eff. 12-30-97)

NAC 534.210 “Waste” defined. “Waste” has the meaning ascribed to it in NRS 534.0165.

[St. Engineer, Drilling Wells Reg. § 1.21, eff. 5-19-81]—(NAC A 1-9-90)

NAC 534.220 “Well” defined. (NRS 534.020, 534.110) “Well” means a penetration in the ground made for the purpose of measuring, testing or sampling the underground strata or producing ground water. The term includes a water well, monitoring well or exploratory well.

[St. Engineer, Drilling Wells Reg. § 1.22, eff. 5-19-81]—(NAC A 1-9-90; 12-30-97)

NAC 534.235 “Well bore” defined. (NRS 534.020, 534.110) “Well bore” means a cylindrical hole made in the construction or drilling of a well.

(Added to NAC by St. Engineer, eff. 12-30-97)

NAC 534.240 “Well driller” defined. “Well driller” has the meaning ascribed to it in NRS 534.017.

[St. Engineer, Drilling Wells Reg. § 1.24, eff. 5-19-81]—(NAC A 1-9-90)

NAC 534.420 Plugging of well: General requirements. (NRS 534.020, 534.110)

1. Except as otherwise provided in NAC 534.422, wells must be plugged in the manner prescribed in this section by a driller licensed by the state engineer.

2. A driller shall:
   (a) Ensure that a notice of his intent to plug a water well is received by the division not less than 3 working days before the drill rig is moved to the location where the well will be plugged; and
   (b) Notify the division not less than 24 hours before he begins to plug the well.

3. Before the driller begins to plug the well, he shall, if possible, obtain the log and record of work for that well from the division or the owner of the well.

4 On abandonment or order of the state engineer, a water well must be plugged by:

(a) Removing the pump or debris from the well bore with appropriate equipment; and

(b) If an annular cement seal was not installed, breaking the casing free with appropriate equipment so that the casing may be pulled from the well.

5. If the casing in the well:

(a) Breaks free, the driller shall plug the borehole in the manner prescribed in NAC 534.4371 as the casing is pulled from the well or after the casing is removed from the well if the borehole remains intact. The well must be plugged from the total depth of the well to the surface of the well, in stages if necessary, to displace in an upward direction any fluid or debris in the well.

(b) Does not break free, the driller shall perforate that portion of the casing which extends from the bottom of the well to not less than 50 feet above the top of the uppermost saturated ground water stratum. That portion of the casing must be perforated not less than four times per linear foot to allow the plugging fluid to penetrate the annular space and the geologic formation. The perforations made in each linear foot of the casing must be made along a horizontal plane of the well bore. The angle between any two consecutive perforations made on a horizontal plane must not exceed 90 degrees, as measured from the center of the well bore. A well with a diameter of more than 8 inches in nominal size must be perforated a sufficient number of additional times per linear foot to ensure that the plugging fluid penetrates into the annular space and formation. The well driller shall then plug the well from the total depth of the well to 50 feet above the uppermost saturated ground water stratum or to within 20 feet of the surface of the well, whichever is less, with neat cement or bentonite grout specifically designed to plug abandoned wells.

6. The well driller shall place a surface plug in the well consisting of neat cement, cement grout or concrete grout, from a depth of at least 20 feet to the surface.

7. If the well casing does not break free and there is no evidence of a sanitary seal around the well casing, the driller shall, in addition to the requirements of subsection 5, perforate the upper 50 feet of casing before setting the surface plug. The casing must have at least four perforations per linear foot of casing and the surface plug must consist of neat cement.

8. A well driller shall submit a written report to the division within 30 days after a water well has been plugged. The report must contain the location of the well by public survey and county assessor's parcel number, the name of the owner of the well, the condition of the well, the static water level before plugging and a detailed description of the method of plugging, including, but not limited to:

(a) The depth of the well;

(b) The depth to which the materials used to plug the well were placed;

(c) The type, size and location of the perforations which were made in the casing;

(d) The debris encountered in, milled out of or retrieved from the well; and

(e) The materials used to plug the well.

9. If there is any standing liquid in the interval of the well bore that is being plugged, all grout materials used pursuant to this section must be placed by tremie pipe in an upward direction.
[St. Engineer, Drilling Wells Reg. Part 14, eff. 5-19-81]—(NAC A 1-9-90; 12-30-97)

NAC 534.422 Plugging of well: Use of exceptional method. (NRS 534.020, 534.110)

1. A well driller who wishes to plug a well in a manner that does not comply with the provisions set forth in NAC 534.420 must request approval from the division.
2. If the division authorizes the well driller to plug the well in a manner other than the manner set forth in NAC 534.420, the well driller shall comply with the instructions he receives from the division, if any, relating to the manner in which the well must be plugged.
(Added to NAC by St. Engineer, eff. 12-30-97)

NAC 534.424 Plugging of well: Responsibility for cost. (NRS 534.020, 534.110)

1. If a well is located on private land, the owner of the land at the time the well is plugged is responsible for the cost of plugging the well.
2. If a well is located on public land, the person who last drilled or used the well is responsible for the cost of plugging the well. If the person who last drilled or used the well does not plug the well within 1 year after receiving notice from the division by certified mail, return receipt requested, that the well must be plugged, the person who owns the land on which the well is located must plug the well.
(Added to NAC by St. Engineer, eff. 12-30-97)

NAC 534.427 Mandatory plugging of certain wells. (NRS 534.020, 534.110)

1. If any type of permit, waiver or application to appropriate water from a water well is canceled, abrogated, forfeited, withdrawn or denied, the well must be plugged in the manner prescribed in NAC 534.420.
2. A well, other than a water well drilled for a domestic purpose, for which a permit or waiver has not been issued must also be plugged in the manner prescribed in NAC 534.420.
(Added to NAC by St. Engineer, eff. 1-9-90; A 12-30-97)

NAC 534.4365 Monitoring wells: Plugging. (NRS 534.020, 534.110)

1. Except as otherwise provided in this section, a monitoring well must be plugged in the manner prescribed in NAC 534.420 within 3 days after it is abandoned.
2. Except as otherwise provided in subsections 3 and 4, a monitoring well may be plugged by:

   (a) Placing neat cement or a high-solids bentonite grout, which consists of not less than 20 percent bentonite, by tremie pipe in an upward direction from the bottom of the well to the surface; or
   (b) Placing sodium bentonite pellets or granules or bentonite grout from the bottom of the well to 20 feet below the surface and placing neat cement from 20 feet below the surface to the surface. Sodium bentonite pellets or

granules may not be placed in more than 100 feet of standing liquid unless the pellets or granules have been coated by the manufacturer to delay hydration.

3. The casing in the monitoring well must be removed from the well bore if:
   (a) The soil or water in the well is contaminated;
   (b) The well was not constructed pursuant to the provisions of this chapter; or
   (c) The well was constructed by a person who is not a licensed well driller. Except as otherwise provided in subsection 4, neat cement or high-solids bentonite grout must be placed by tremie pipe in an upward direction from the bottom of the well to the surface as the casing is removed from the well bore.
4. If the integrity of the borehole remains intact as the casing is removed from the well bore, the well may be plugged as provided in NAC 534.4371.
   (Added to NAC by St. Engineer, eff. 12-30-97)

NAC 534.4367 Drive point wells. (NRS 534.020, 534.110)

1. A well driller may construct a drive point well without placing in the annular space of the well the gravel pack and seals required pursuant to NAC 534.4357.
2. The diameter of the casing used in a drive point well which is not constructed pursuant to the provisions of NAC 534.4357 must not be larger than 2 inches in nominal size.

3. A drive point well which is not constructed pursuant to the provisions of NAC 534.4357 must be abandoned within 60 days after the well is constructed. Upon abandonment, the casing must be removed from the well bore and the well bore must be plugged in the manner provided in NAC 534.4371.
   (Added to NAC by St. Engineer, eff. 12-30-97)

NAC 534.4369 Boreholes: Generally. (NRS 534.020, 534.110)

1. A borehole may be drilled or plugged by a person who is not a licensed well driller.
2. A person who constructs a borehole is not required to file with the division a notice of intent to drill or plug the borehole.
3. A borehole may be drilled without obtaining from the division a permit to appropriate water or a waiver of the requirement to obtain such a permit.
4. A person who drills or plugs a borehole, the operator of the exploration project or the owner of the land where the borehole is located must maintain a record of the drilling operation which includes:

   (a) The dates on which the borehole is constructed and plugged;
   (b) The location of the borehole as shown by public survey;
   (c) The depth and diameter of the borehole;
   (d) The depth at which ground water is encountered in the borehole; and
   (e) The methods and materials used to plug the borehole.

5. The state engineer may, at any time, require the person drilling or plugging the borehole, the operator of the exploration project or the owner of the land on which the borehole is located to submit to the state engineer a copy of the record required pursuant to subsection 4 and any other information relating to the construction, operation or plugging of the borehole that the state engineer determines is necessary.

6. The owner and the lessor of the land on which a borehole is located, the operator of the exploration project and the drilling or plugging contractor for the project shall ensure that the ground water is uncontaminated during the drilling, operation or plugging of the borehole.
(Added to NAC by St. Engineer, eff. 12-30-97)

NAC 534.4371 Boreholes: Plugging requirements; measures required if contaminant or contaminated water is encountered. (NRS 534.020, 534.110)

1. A borehole must be plugged within 60 days after it is drilled.
2. Except as otherwise provided in subsections 3 and 4, a borehole must be plugged:

    (a) In the manner prescribed in NAC 534.420;
    (b) If the highest saturated stratum is not more than 60 feet above the bottom of the borehole, by placing concrete grout, cement grout, neat cement or bentonite grout by tremie pipe in an upward direction from the bottom of the borehole to the surface or by placing sodium bentonite chips or pellets specifically designed to be used to plug boreholes from the bottom of the borehole to the surface; or
    (c) If the highest saturated stratum encountered in the borehole is more than 60 feet above the bottom of the borehole, by:

        (1) Plugging the portion of the borehole from the bottom to 50 feet above the highest saturated stratum encountered in the borehole in the manner described in paragraph (a);
        (2) Backfilling the portion of the borehole that extends from the materials placed in the borehole pursuant to subparagraph (1) to 10 feet from the surface with compacted soil which is uncontaminated; and
        (3) Placing any of the materials described in paragraph (a) from 10 feet below the surface to the surface.

3. If a contaminant or contaminated water is encountered in a borehole, the strata that contain the contaminant or contaminated water must be sealed in the manner prescribed in subsection 2 to prevent the contaminant or contaminated water from commingling with other strata or the water contained in other strata. The vertical movement of contaminants in the well bore must be prevented.

4. If the elevation of the bottom of the borehole is more than 50 feet above the preexisting natural elevation of any saturated ground water stratum, the borehole must be plugged by:

(a) Backfilling the borehole from the bottom to 10 feet from the surface with compacted soil which is uncontaminated; and
(b) Placing any of the materials described in paragraph (b) of subsection 2 from 10 feet below the surface to the surface.

5. If bentonite grout is used to plug a borehole, it must be mixed pursuant to the specifications recommended by the manufacturer.

6. If sodium bentonite chips or pellets or uncontaminated soil are placed in the borehole, they must be placed in such a manner that a bridge does not occur. Sodium bentonite chips or pellets may not be placed in more than 100 feet of standing liquid unless the chips or pellets have been coated by the manufacturer to delay hydration.

7. If casing is set in a borehole, the borehole must be completed as a well pursuant to the provisions of this chapter. The borehole must be plugged pursuant to NAC 534.420, or the casing must be removed from the borehole when it is plugged. The upper portion of the borehole may be permanently cased if the annular space between the casing and the walls of the borehole is completely sealed from the bottom of the casing to the surface pursuant to NAC 534.380.
(Added to NAC by St. Engineer, eff. 12-30-97)

NAC 534.4373 Boreholes: Responsibility for plugging. (NRS 534.020, 534.110) The owner and lessor of the land on which a borehole is located, the operator of the exploration project and the plugging contractor for the project are jointly and severally responsible for plugging the borehole pursuant to this chapter.
(Added to NAC by St. Engineer, eff. 12-30-97)

NAC 534.4375 Boreholes, blast holes and seismic shot holes: Artesian conditions. (NRS 534.020, 534.110) If an artesian condition is encountered in any borehole, blast hole or seismic shot hole, the artesian water strata must be contained pursuant to NRS 534.060 and NAC 534.378, and the borehole, blast hole or seismic shot hole must be sealed by the method described in subsection 2 of NAC 534.4371. The owner and lessor of the land on which a borehole is located, the operator of the exploration project and the drilling contractor for the project shall take the necessary steps to prevent the loss of water above or below the surface and to prevent the vertical movement of water in the well bore.
(Added to NAC by St. Engineer, eff. 12-30-97)

DISCLAIMER
This SOP provided general guidance for TIMET contractors and subcontractors for technical issues addressed during environmental site investigation and remediation activities. It is noted, however, that each site and project is unique and these guidelines are not a substitute for common sense and good management practices based on professional training and experience. In addition, individual contract terms may affect the implementation of this SOP. TIMET contractors reserve the unrestricted right to change, modify or not apply these guidelines in their sole, complete, and unrestricted discretion to meet certain circumstances, contractual requirements, site conditions, or job requirements.

1.0 INTRODUCTION

Groundwater monitoring wells are designed and installed for a variety of reasons, including: (1) detecting the presence of contaminants, (2) collecting groundwater samples representative of in situ aquifer chemical characteristics, or (3) measuring water levels for determining groundwater potentiometric head and groundwater flow direction.

Although detailed specifications for well installation may vary in response to site-specific conditions, some elements of well installation are common to most situations. This Standard Operating Procedure (SOP) is based on widely recognized methods described by the U.S. Environmental Protection Agency (EPA) and American Society for Testing and Materials (ASTM). However, well type, well construction, and well installation methods will vary with drilling method, intended well use, subsurface characteristics, and other site-specific criteria. Monitoring wells should be constructed and installed in a manner consistent with all local and state regulations, specifically, the Regulations for Water Well and Related Drilling (NDEP 1998). Detailed specifications for well installation should be identified within a project-specific sampling and analysis plan.

General specifications and procedures for the following monitoring well components are included in this SOP:

- Monitoring well materials
  - Casing materials
  - Well screen materials
  - Filter pack materials
  - Annular sealant (bentonite pellets or chips)
  - Grouting materials
  - Tremie pipe
  - Surface completion and protective casing materials

- Monitoring well installation procedures
  - Well screen and riser placement
  - Filter pack placement
  - Temporary casing retrieval
  - Annular seal placement
  - Grouting
  - Surface completion and protective casing (aboveground and flush-mount)
  - Concrete surface pad and bumper posts
  - Permanent and multiple casing well installation

- Recordkeeping procedures
  - Surveying
  - Permits and well construction records
  - Monitoring well identification

Well installation methods will depend to some extent on the boring method. Specific boring or drilling protocols are detailed SOP No. 51, Drilling Methods. The boring method, in turn, will depend on site-specific geology and hydrogeology and project requirements. Boring methods commonly used for well installation include:

- Hollow-stem augering
- Rota-sonic
- Air rotary casing hammer

1.1 PURPOSE

This SOP establishes the requirements and procedures for monitoring well installation. Monitoring wells should be designed to function properly throughout the duration if the monitoring program. The performance objectives for monitoring well installation are as follows:

- Ensure that the monitoring well will provide water samples representative of in situ aquifer conditions.
- Ensure that the monitoring well construction will last for duration the of the project.
- Ensure that the monitoring well will not serve as a conduit for vertical migration of contaminants, particularly vertical migration between discrete aquifers.
- Ensure that the well diameter is adequate for all anticipated downhole monitoring and sampling equipment.

1.2 SCOPE

This SOP applies to the installation of monitoring wells. Although some of the procedures may apply to the installation of water supply wells, this SOP is not intended to cover the design and construction of such wells. This SOP identifies several well drilling methods related to monitoring well installation, but the scope of this SOP does not include drilling methods.

Other relevant SOPs include SOP-7, Equipment Decontamination; SOP-50, Soil Sampling; SOP-51, Drilling Methods; SOP-101, Groundwater Monitoring Well Development, and SOP-103, Groundwater Sampling using Mircopurge Technology.

1.3 DEFINITIONS

Annulus: The space between the monitoring well casing and the wall of the well boring.

Bentonite seal: A colloidal clay seal separating the sand pack from the annular grout seal.

Centalizer: A stainless-steel or plastic spacer that keeps the well screen and casing centered in the borehole.

Filter pack: A clean, uniform sand or gravel placed between the borehole wall and the well screen to prevent formation material from entering the screen.

Grout seal: A fluid mixture of (1) bentonite and water, (2) cement, bentonite, and water, or (3) cement and water placed above the bentonite seal between the casing and the borehole wall to secure the casing in place and keep water from entering the borehole.

Tremie pipe: A rigid pipe used to place the well filter pack, bentonite seal, or grout seal. The tremie pipe is lowered to the bottom of the well or area to be filled and pulled up ahead of the material being placed.

Well casing: A solid piece of pipe, typically polyvinyl chloride (PVC) or stainless steel, used to keep a well open in either unconsolidated material or unstable rock.

Well screen: A PVC or stainless steel pipe with openings of a uniform width, orientation, and spacing used to keep materials other than water from entering the well and to stabilize the surrounding formation.

1.4 REFERENCES

The following references are useful for constructing monitor wells and injection/extraction wells. Nevada Administrative Code (NAC) Chapter 534 – Underground Water and Wells – prescribes well construction requirements by rule, and must be followed. NAC 534 is attached to this SOP and is considered integral and part of it.

American Society for Testing and Materials. 1995. Standard Practice for Design and Installation of Ground Water Monitoring Wells in Aquifers. D5092-90. West Conshohocken, Pennsylvania

California Department of Toxic Substances Control. 1994. Monitoring Well Design and Construction for Hydrogeologic Characterization. Guidance for Groundwater Investigations. August.

Driscoll, F.G. 1986. Groundwater and Wells (Second Edition). Johnson Division, UOP, Inc. St. Paul, Minnesota.

U.S. Environmental Protection Agency (EPA). 1986. RCRA Ground Water Monitoring Technical Enforcement Guidance Document. Office of Solid Waste and Emergency Response. Washington, DC. OSWER-9950-1. September.

EPA. 1991. Handbook of Suggested Practices for the Design and Installation of Ground-Water Monitoring Wells. Office of Research and Development, Environmental Monitoring Systems Laboratory. Washington, DC. EPA/600-4-89/034. March. On-Line Address: http://www,epa.gov/swerust1/cat/wwelldct.pdf

EPA. 1994. Monitor Well Installation. Environmental Response Team SOP #2048 (Rev. #0.0,03/18/96). On-Line Address: http://www.ert.org.media_resrcs/media_resrcs.asp?Child1

NAC Chapter 534. Underground Water and Wells

State of Nevada Department of Environmental Protection (NDEP). 1998. Regulations for Water Wells and Related Drilling. Revised and Adopted January 1998.

2. 0 MONITORING WELL CONSTRUCTION MATERIALS

Monitoring well construction materials should be specified in the project-specific sampling and analysis plan as well as in the statement of work for any subcontractors assisting in the well installation. Well construction materials that come in contact with groundwater should not measurably alter the chemical quality of groundwater samples with regard to the constituents being examined. The riser, well screen, and filter pack and annular sealant placement equipment should be steam cleaned or high-pressure water cleaned immediately prior to well installation. Alternatively, these materials can be certified by the manufacturer as clean and delivered to the site in protective wrapping. Samples of the filter pack, annular seal, and mixed grout should be retained as a quality control measure until at least one round of groundwater sampling and analysis is completed.

This section discusses material specifications for the following well construction components: casing, well screen, filter pack, annular sealant (bentonite pellets or chips), grout, tremie pipes, surface completion components (protective casing, lockable and water tight cap, and padlock), concrete surface pad, and uncontaminated water. The Monitoring Well Construction Diagram (Figure 1) shows the construction details of a typical monitoring well.

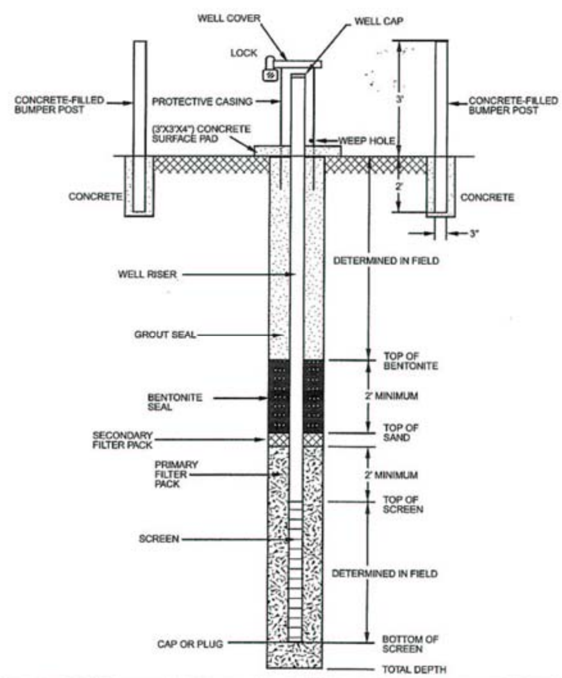


Figure 1 Monitoring Well Completion Diagram

2.1 CASING DIAMETER AND SCREEN LENGTH

Screen length and monitoring well diameter will depend on site-specific considerations such as intended well use, contaminants of concern, and hydrogeology. Some specific considerations include the following:

- Water table wells should have screens of sufficient length and diameter to monitor the water table and provide sufficient sample volume under high and low water table conditions.
- Wells with low recharge should have screens of sufficient length and diameter so that adequate sample volume can be collected.
- Wells should be screened over sufficiently short intervals to allow for monitoring of discrete migration pathways.
- Where light nonaqueous-phase liquids (LNAPL) or contaminants in the upper portion of a hydraulic unit are being monitored, the screen should be set so that the upper portion of the water-bearing zone is below the top of the screen.
- Where dense nonaqueous-phase liquids (DNAPL) are being monitored, the screen should be set within the lower portion of the water-bearing zone, just above a relatively impermeable lithologic unit.
- The screened interval should not extend across an aquiclude or aquitard.
- If contamination is known to be concentrated within a portion of a saturated zone, the screen should be constructed in a manner that minimizes the potential for cross-contamination within the aquifer.
- If downhole geophysical surveys are to be conducted, the casing and screen must be of sufficient diameter and constructed of the appropriate material to allow for effective use of the geophysical survey tools.
- If aquifer tests are to be conducted in a monitoring well, the slot size must allow sufficient flux to produce the required drawdown and recovery. The diameter of the well must be sufficient to house the pump and monitoring equipment, and allow sufficient water flux (in combination with the screen slot size) to produce the required drawdown or recovery.

2.2 CASING AND SCREEN MATERIALS

Well screens should be new, machine-slotted or continuous wrapped wire-wound, and composed of materials most suited for the monitoring environment based on site characterization findings. Well screens are generally constructed of the same materials used for well casing (PVC or stainless steel). Monitoring well casing is specified by diameter, thickness, and type of material. Casing thickness is referred to as "schedule." Polyvinyl chloride (PVC) is usually Schedule 40 (thinner wall), although Schedule 80 (thicker wall) is sometimes used for deep wells. Steel casing is typically Schedule 5 or 10.

Selection of casing and screen material must be based on three primary characteristics: chemical interference potential, chemical resistance, and physical strength. The materials must not assimilate chemicals either by adsorption onto the material surface or absorption into the material matrix or pores; they must be durable enough to withstand potential chemical attacks either from natural chemical constituents or groundwater contaminants; and they must have the structural strength to withstand the forces exerted on them by the surrounding geologic materials and during installation. The three components of casing and screen structural strength are tensile strength, compressive (column) strength, and collapse strength. Casing and screen materials generally available are Teflon, PVC, stainless steel, galvanized steel, carbon steel, and low-carbon steel.

The two most commonly used materials are PVC and stainless steel. PVC is inexpensive, widely available, lightweight, and easy to work with. However, the column strength of PVC may limit the depth of installation. Schedule 80 PVC may be used for deeper wells; however, the reduced inside diameter should be taken into account when designing the well. Many studies have been conducted concerning the effect of PVC on water quality data. Whereas adsorption of some chlorinated species to PVC was documented, the adsorption rate was found to be very slow. Because a sample is generally taken shortly after the purging of stagnant water in contact with the casing, the contaminants in the water will have minimal time to be influenced by sorption or leaching effects. Therefore, potential sample bias effects due to interactions with PVC appear to be negligible.

Steel well materials are stronger, more rigid, and less temperature sensitive than PVC or Teflon. Stainless steel has the highest corrosion resistance of the various types of steel. Type 304 and Type 316 are the most commonly used stainless steels. Both are available in low-carbon forms, which are more easily welded than the normal carbon steel. Low-carbon steel is designated by an "L" after the number (e.g., Type 304L). Type 304 stainless steel is superior to Type 316 from a corrosion resistance and cost standpoint. Type 316 is preferred to Type 304 under reducing conditions. For either type of stainless steel, long-term exposure to corrosive conditions may result in chromium or nickel contamination of groundwater samples. Insoluble halogen and sulfur compounds may also form as a result of corrosion of stainless steel.

Threaded, flush-joint casing is preferred for monitoring well applications. Welded-joint steel casing may also be acceptable, but is typically more expensive and inconvenient. Glued PVC should never be used for monitoring wells since the glue may release organic contamination into the well. The casing should have a well cap that is vented to prevent the accumulation of gases and to allow water levels in the well to respond to barometric and hydraulic pressure changes.

The hydraulic efficiency of a well screen depends primarily upon the amount of open area available per unit length of screen. The two screen types commonly used for monitoring wells are machine-slotted, and continuous-slot wire-wound. Hand-slotted, drilled, or perforated casings should not be used as well screens. Slotted casing is manufactured from a variety of materials, including PVC and stainless steel. Slot openings are designated by numbers that correspond to the widths of the openings in thousandths of an inch (e.g., number 10 slot refers to 0.010-inch slot size). The slots have a consistent width for the entire wall thickness of the casing, which can result in clogging if irregularly shaped formation particles are brought through the screen during well development and sampling. The continuous-slot, wire-wound screen has a greater area per opening per length and diameter than is available with any other screen type. The percentage of open area in continuous-slot screen is often more than twice that provided by standard slotted well screen. The triangular shaped wire makes these screens non-clogging. They are fabricated in PVC and a variety of metals and are used when high pumping rates are anticipated. If a monitoring well will also be used for hydraulic testing, the well screen open area should equal or exceed the formation's effective porosity so that the screen is not the limiting factor in formation hydraulic testing. In most cases, this amount of open area can only be achieved through the use of continuous-slot, wire-wound well screen.

In choosing between types of well screens, another factor is the speed and effectiveness of well development. Screens with a high percentage of open area greatly reduce the time and effort required for well development. The bottom of the screen must be sealed by an endcap consisting of the same material as the screen. In the case of wells deeper than 150 feet deep, schedule-80 PVC will be used to minimize the potential for casing blistering when grout cures. The diameter of the screen and casing will be a maximum of 4 inches less than the diameter of the borehole. Stainless steel centralizers will be placed at the top and bottom of the well screen and every 40 feet along the blank casing. The bottom of each well will consist of a slip cap mounted with stainless steel screws to a flush threaded end-cap. Holes of 1/16-inch diameter will be drilled through both caps prior to installation to prevent water from sitting in the bottom of the well if the static water level drops below the bottom of the well. A locking cap or dedicated pump assembly will be used to secure the top of the well.

2.3 DECONTAMINATION OF CASING AND SCREEN MATERIALS

During the production of PVC casing, a wax layer can develop on the inner wall of the casing; protective coatings may also be added to enhance casing durability. Considerable quantities of oils and solvents are used during the manufacturing and machining of threads during the production of steel casing. All of these represent potential sources of chemical interference and must be removed either with a laboratory-grade nonphosphate solution or by steam cleaning prior to installation. Factory cleaning of casing and screens in a controlled environment by standard detergent washing, rinsing, and air-drying procedures is superior to any cleaning efforts attempted in the field. Factory cleaned and sealed casing and screens can be certified by the supplier.

2.4 FILTER PACK AND WELL SCREEN DESIGN

A properly designed monitoring well requires that a well screen be placed opposite the zone to be monitored and be surrounded by materials that are coarser and of greater hydraulic conductivity than the natural formation material. Naturally developed wells and wells with artificially introduced filter pack are the two basic types of well intake designs for unconsolidated or poorly consolidated materials.

2.4.1 Naturally Developed Wells

In naturally developed wells, the formation materials are allowed to collapse around the well screen. Naturally developed wells can be installed in which natural formation materials are relatively coarse grained, permeable, and of uniform grain size. It is essential that the grain-size distribution of the formation to be monitored is accurately determined by conducting a mechanical (sieve) analysis of samples taken from the interval to be screened. After sieving, a plot of grain size versus cumulative percentage of sample retained on each sieve is made. Well screen slot sizes are based on the grain-size distribution, specifically the effective size (the sieve size that retains 90 percent of the formation material, referred to as D10) and the uniformity coefficient (the ratio of the sieve size that retains 40 percent of the material or D60, to the effective size). A naturally developed well can be justified if the effective grain size is greater than 0.010 inch and the uniformity coefficient is greater than 3.0. Various state agencies (e.g., the California Department of Toxic Substances Control [DTSC]) recommend that an artificial filter pack be used if sieve analysis indicates that a screen slot size of 0.020 inches or less is required to retain 50 percent of the natural formation. The biggest drawback for naturally developed wells is the time required for well development to remove fine-grained formation material.

2.4.2 Artificial Filter-Packed Wells

Filter packs are installed to create a permeable envelope around the well screen. The use of an artificial filter pack in a fine-grained formation material allows the screen slot size to be considerably larger than if the screen were placed in the formation material without the filter pack. The selection of the filter pack grain size should be based on the grain size of the finest layer to be screened. Filter pack grain size and well screen slot size should be determined by the grain size distribution of the formation material. The filter pack should be designed first. It is recommended to use a filter pack grain size that is three to five times the average (D50) size of the formation materials. However, this method may be misleading in coarse, well-graded formation materials. Another way to determine filter pack grain size is to take the D30 grain size of the formation materials and multiply it by a factor of between three and six, with three used if the formation is fine and uniform and six used if the formation is coarse and non-uniform. For both methods, the uniformity coefficient of the filter pack materials should be as close to 1.0 as possible (2.5 maximum) to minimize particle size segregation during filter pack installation.

The filter pack should extend from the bottom of the well screen to approximately 2 to 5 feet above the top of the screen to account for settlement of the pack material during development and to act as a buffer between the well screen and the annular seal. A secondary filter pack (transitions sand) is sometimes used to prevent annular grout seal materials from migrating into the primary filter pack. The secondary filter pack should extend at least one foot above the top of the primary filter pack. It should consist of a uniformly graded fine sand with 100 percent passing a No. 30 U.S. Standard sieve and less than 2 percent by weight passing the 200 sieve. Filter pack thickness must be sufficient to surround the well screen but thin enough to minimize resistance to the flow of fine-grained formation material and water into the well during development.

American Society of Testing and Materials (ASTM), Designation D 5092-90, recommends that a minimum of 2-inch thick filter pack between the borehole well and the well casing (ASTM 1995). The materials comprising the filter pack should be as chemically inert as possible. It should be comprised of clean quartz sand or glass beads. Filter pack materials usually come in 100-pound bags; these materials are washed, dried, and factory packaged. The size of well intake openings can only be selected after the filter-pack grain size is specified. The slot size should be such that 90 to 100 percent of the filter-pack material is held back by the well screen. The casing string should be installed in the center of the borehole. This will allow the filter-pack materials to evenly fill the annular space around the screen and ensure that annular seal materials fill the annular space evenly around the casing.

If a hollow-stem auger or dual-tube rig is used, the auger or inner tube of the dual tube will adequately centralize the casing string. For other types of drilling, centralizers should be used to ensure the casing string is positioned in the center of the borehole. Centralizers are typically expandable stainless steel metal or plastic that attach to the outside of the casing and are adjustable along the length of the casing. Centralizers are generally attached at the bottom and immediately above the well screen and at 10- or 20-foot intervals along the casing to the surface. Methods for filter pack emplacement include gravity (free-fall), tremie pipe, reverse circulation, and backwashing. The latter two techniques are not commonly used for monitoring well construction, since they require the introduction into the borehole of water from a surface source. Gravity emplacement is only possible in relatively shallow wells with an annular space of more than 2 inches, where the potential occurrence of bridging is minimized. Bridging can result in the occurrence of large unfilled voids in the filter pack or the failure of filter pack materials to reach their intended depth. Gravity emplacement may also cause filter pack gradation. Additionally, formation materials from the borehole wall can become incorporated into the filter pack, potentially contaminating it. With the tremie emplacement method, the filter pack is poured or slurried into the annular space adjacent to the well screen through a rigid pipe, usually 1.5 inches in diameter. Initially, the pipe is positioned so that its end is at the bottom of the annulus.

If the filter pack is being installed in a temporarily cased borehole (hollow-stem auger or air rotary casing hammer), the temporary casing is pulled to expose the screen as the filter-pack material builds up around the well screen. In unconsolidated formations, the temporary casing should only be pulled out 1 to 2 feet at a time to prevent caving. In consolidated or well-cemented formations or in cohesive unconsolidated formations, the temporary casing may be raised well above the bottom of the borehole prior to filter pack emplacement.

For deep wells and/or non-uniform filter pack materials, the filter pack may be pressure fed through a tremie pipe with a pump. Emplacement should be continuously monitored with a weighted measuring tape accurate to the nearest 0.1 foot to determine when the filter pack has reached the desired height. After reaching the desired height, the well should be surged for 10 to 15 minutes, then checked for settling. Add more filter pack as necessary. Record the volume of filter pack used and check against calculated volume of annular space. Most well designs also employ a "secondary" filter pack (transition sand) above the primary filter pack for purposes of reducing bentonite seal and grout migration into the primary filter pack. If applicable, care must be taken so that the filter pack materials are not installed into a hydrostratigraphic unit above or below the specific zone that is targeted for monitoring.

2.5 ANNULAR SEAL

Proper annular seal formulation and placement results in the complete filling of the annular space and envelopes the entire length of the well casing to ensure that no vertical migration can occur within the borehole. Annular seal materials may include bentonite (sodium montmorillonite), neat cement grout, or variations of both.

Typically, a bentonite seal from 2 to 5 feet thick is emplaced immediately above the filter pack. The use of bentonite as a sealing material depends on its efficient hydration following emplacement. Expansion of bentonite in water can be on the order of eight to 10 times the volume of dry bentonite. This expansion causes the bentonite to provide a tight seal between the casing and the adjacent formation and between the grout and filter pack. Bentonite is available as pellets, granules, chips, chunks, or powder. The dry bentonite should be less than one-fifth the width of the annular space between casing and borehole (ASTM 1995). If the bentonite seal will be above the saturated zone, several gallons of clean water must be poured down the annulus to begin the hydration process. A minimum of 30 minutes should pass to allow for hydration before additional annular seal materials are placed above the bentonite. Bentonite pellets having a coating to slow the hydration process are not recommended as they have been found to contain chemicals that may impact water quality.

Powdered bentonite is generally made into a grout slurry to allow emplacement as a bentonite seal. This grout slurry is prepared by mixing about 15 pounds of a high-solids, low-viscosity bentonite with seven gallons of water to yield one cubic foot of grout. Once the grout is mixed, it should remain workable for 15 to 30 minutes. During this time the grout is pumped through a tremie pipe with a mud or grout pump. Once in place, the bentonite grout requires a minimum of 24 hours to strengthen. In water with a high total dissolved solids (TDS) content (>5,000 parts per million [ppm]) or a high chloride content, the swelling of bentonite is inhibited. A neat cement is commonly used to seal the remainder of the annulus. Neat cement is made up of one 94-pound bag of Portland Cement and 6 gallons of water. The water used to mix the neat cement should be clean with a TDS less than 500 parts per million (ppm). Bentonite powder is often added to neat cement to improve workability and reduce slurry weight and density and to reduce grout shrinkage. The proportion of bentonite by volume should be 3 to 5 percent.

The cement-bentonite grout should be mechanically blended in an aboveground rigid container and pumped through a tremie pipe to within a few inches of the bottom of the space to be sealed. This allows the grout to displace groundwater and loose formation materials up the hole. The end of the tremie pipe should always remain in the grout without allowing air spaces. After emplacement, the tremie pipe should be removed immediately. The grout should be placed in one continuous mass before initial setting of the cement or before the mixture loses its fluidity. Cement is a highly alkaline substance (pH from 10 to 12) and introduces the possibility of altering the chemistry of the water it contacts. Thinner slurries may infiltrate an unprotected filter pack. After a borehole annulus is filled with grout a sample of water may be obtained and the pH determined in the field. A pH reading of 12 or higher may indicate an invasion of cement grout into the well.

2.6 SURFACE COMPLETIONS

Two types of surface completions are common for groundwater monitoring wells: aboveground and flush-mounted. Aboveground completions are preferred wherever practical. The primary purpose of either type of completion is to prevent surface runoff from entering and infiltrating down the annulus of the well, and to protect the well from accidental damage or vandalism. The surface seal may be an extension of the annular seal installed above the filter pack, or a separate seal emplaced atop the annular seal.

For aboveground completions, the drilling subcontractor will construct a concrete apron (3 feet x 3 feet x 0.5 feet) around each well. A protective steel casing fitted with a locking cover is set into the uncured concrete apron. Concrete aprons will be crowned to provide positive runoff away from the well. Concrete pads may be constructed within three days after wells have been installed. If necessary steel guard posts 4-inches in diameter and filled with concrete will be installed around the pads. Posts will be 5 feet long and will have a stickup of 2.5 feet above ground surface and 2.5 feet below ground surface. In a flush-to-ground surface completion, a water-tight monitoring well Christy box or its equivalent is set into the cement surface seal before it has cured. This type of completion is used in high-traffic areas. A low, gently sloping mound of cement will discourage surface runoff. A locking well cap must be used to secure the inner well casing.

3.0 MONITORING WELL INSTALLATION PROCEDURES

This section describes the procedures used to install a single-cased monitoring well, with either temporary casing or hollow-stem augers to support the walls of the boring in unconsolidated formations. The procedures are described in the order in which they are conducted, and include: (1) placement of well screen and riser pipe, (2) placement of filter pack, (3) progressive retrieval of temporary casing, (4) placement of annular seal, (5) grouting, (6) surface completion and installation of protective casing, and (7) installation of concrete pad and bumper posts.

The additional steps necessary to install a well with permanent or multiple casing strings are described at the end of this section.

3.1 WELL SCREEN AND RISER PLACEMENT

After the total depth of the boring is confirmed and the well screen depth interval and the height of the aboveground completion are determined, the screen and riser is assembled from the bottom up as it is lowered down the hole. The following procedures should be followed:

1. Measure the total depth of the boring using a weighted tape.

2. Determine the length of screen and casing materials required to construct the well.

3. Assemble the well parts from the bottom up, starting with the well sump or cap, well screen, and then riser pipe. Progressively lower the assembled length of pipe.

4. The length of the assembled pipe should not extend above the top of the installation rig.

The well sump or cap, well screen, and riser should be certified clean by the manufacturer or should be decontaminated before assembly and installation. No grease, oil, or other contaminants should contact any portion of the assembly. Flush joints should be tightened, and welds should be water tight and of good quality. The riser should extend above grade and be capped temporarily to prevent entrance of foreign materials during the remaining well completion procedures.

When the well screen and riser assembly is lowered to the predetermined level, it may float and require a method to hold it in place. For borings drilled using cable tool or air rotary drilling methods, centralizers should be attached to the riser at intervals of between 20 and 40 feet.

3.2 FILTER PACK PLACEMENT

The filter pack is placed after the well screen and riser assembly has been lowered into the borehole. The steps below should be followed:

1. Determine the volume of the annular space in the filter pack interval. The filter pack should extend from the bottom of the borehole to at least 2 feet above the top of the well screen.

2. Assemble the required material (sand pack and tremie pipe).

3. Lower a clean or decontaminated tremie pipe down the annulus to within 1 foot of the base of the hole.

4. Pour the sand down the tremie pipe using a funnel; pour only the quantity estimated to fill the first foot.

5. Check the depth of sand in the hole using a weighted tape.

6. Pull the drill casing up ahead of the sand to keep the sand from bridging.

7. Continue with this process (steps 4 through 6) until the filter pack is at the appropriate depth.

If bridging of the filter pack occurs, break out the bridge prior to adding additional filter pack material. For wells less than 30 feet deep installed inside hollow-stem augers, the sand may be poured in 1-foot lifts without a tremie pipe.

Sufficient measurements of the depth to the filter pack material and the depth of the bottom of the temporary casing should be made to ensure that the casing bottom is always above the filter pack. The filter pack should extend 2 feet above the well screen (or more if required by state or local regulations). However, the filter pack should not extend across separate hydrogeologic units. The final depth interval, volume, and type of filter pack should be recorded on the Monitoring Well Completion Record (attached).

A secondary filter pack may be installed above the primary filter pack to prevent the intrusion of the bentonite grout seal into the primary filter pack. A measured volume of secondary filter material should be added to extend 1 or 2 feet above the primary filter pack. As with the primary filter pack, a secondary filter pack must not extend into an overlying hydrologic unit. An on-site geologist should evaluate the need for a secondary filter pack by consisting the gradation of the primary filter pack, the hydraulic head difference between adjacent units, and the potential for grout intrusion into the primary filter pack.

The secondary filter material is poured into the annular space through tremie pipe as described above. Water form a source of known chemistry may be added to help place the filter pack into its proper location. The tremie pipe or a weighted line inserted through the tremie pipe can be used to measure the top of the secondary filter pack as work progresses. The amount and type of secondary filter pack used should be recorded on the Monitoring Well Completion Record (attached).

3.3 TEMPORARY CASING RETRIEVAL

The temporary casing or hollow-stem auger should be withdrawn in increments. Care should be taken to minimize lifting the well screen and riser assembly during withdrawal of the temporary casing or auger. It may be necessary to place the top head of the rig on the riser to hold it down. To limit borehole collapse in formations consisting of unconsolidated materials, the temporary casing or hollow-stem auger is usually withdrawn until the lowest point of the casing or auger is at least 2 feet, but no more than 5 feet, above the filter pack. When the geologic formation consists of consolidated materials, the lowest point of the casing or auger should be at least 5 feet, but no more than 10 feet, above the filter pack. In highly unstable formations, withdrawal intervals may be much less. After each increment, the depth to the primary filter pack should be measured to check that the borehole has not collapsed or that bridging has not occurred.

3.4 ANNULAR SEAL PLACEMENT

A bentonite pellet, chip, or slurry seal should be placed between the borehole and the riser on top of the primary or secondary filter pack. This seal retards the movement of grout into the filter pack. The thickness of the bentonite seal will depend on state and local regulations, but the seal should generally be between 3 and 5 feet thick.

The bentonite seal should be installed using a tremie pipe, lowered to the top of the filter pack, and slowly raised as the bentonite pellets or slurry fill the space. Care must be taken so that bentonite pellets or chips do not bridge in the augers or tremie pipe. The depth of the seal should be checked with a weighted tape or the tremie pipe.

If a bentonite pellet or chip seal is installed above the water level, water from a known source should be added to allow proper hydration of the bentonite. Sufficient time should be allowed for the bentonite seal to hydrate. The volume and thickness of the bentonite seal should be recorded on the Monitoring Well Completion Record (attached).

3.5 GROUTING

Grouting procedures vary with the type of well design. The volume of grout needed to backfill the remaining annular space should be calculated and recorded on the Monitoring Well Completion Record (Figure 1). The use of alternate grout materials, including grouts containing gravel, may be necessary to control zones of high grout loss. Bentonite grouts should not be used in arid regions because of their propensity to desiccate. Typical grout mixtures include the following:

- Bentonite grout: about 1 to 1.25 pounds of bentonite mixed with 1 gallon of water
- Cement-bentonite grout: about 5 pounds of bentonite and one 94-pound bag of cement mixed with 7 to 8 gallons of water
- Cement grout: one 94-pound bag of cement mixed with 6 to 7 gallons of water

The grout should be installed by gravity feed through a tremie pipe. The grout should be mixed in batches in accordance with the appropriate requirements and then pumped into the annular space until full-strength grout flows out at the ground surface without evidence of drill cuttings or fluid. The tremie pipe should then be removed to allow the grout to cure.

The riser should not be disturbed until the grout sets and cures for the amount of time necessary to prevent a break in the seal between the grout and riser. For bentonite grouts, curing times are typically around 24 hours; curing times for cement grouts are typically 48 to 72 hours. However, the curing time required will vary with grout content and climate conditions. The curing time should be documented in the Monitoring Well Completion Record (attached).

3.6 SURFACE COMPLETION AND PROTECTIVE CASING

Aboveground completion of the monitoring well should begin once the grout has set (no sooner than 24 hours after the grout was placed). The protective casing is lowered over the riser and set into the cured grout. The protective casing should extend below the ground surface to a depth below the frost line (typically 3 to 5 feet, depending on local conditions). The protective casing is then cemented in place. A minimum of 6 inches of clearance should be maintained between the top of the riser and the protective casing. A 0.5-inch diameter drainage or weep hole should be drilled in the protective casing approximately 6 inches above the ground surface to enable water to drain out of the annular space between the casing and riser. A water-tight cap should be placed on top of the riser to seal the well form surface water infiltration in the event of a flood. A lock should be placed on the protective casing to prevent vandalism.

For flush-mounted monitoring wells, the well cover should be raised above grade and the surrounding concrete pad sloped so that water drains away from the cover. The flush-mount completion should be installed in accordance with applicable state local regulations.

3.7 CONCRETE SURFACE PAD AND BUMPER POSTS

The concrete pad installed around the monitoring well should be sloped so that the drainage will flow away from the protective casing and off the pad. The finished pad should extend at least 1 inch below grade. If the monitoring wells are located in high traffic areas, a minimum of three bumper posts should be installed in a radial pattern around the protective casing, outside the cement pad. Specifications for concrete surface pads and bumper posts are described in section 2.6.

3.8 PERMANENT AND MULTIPLE CASING WELL INSTALLATION

When wells are installed through multiple saturated zones, special well construction methods should be used to assure well integrity and limit the potential for cross-contamination between geologic zones. Generally, these types of wells are necessary if relatively impermeable layers separate hydraulic units. Two procedures that may be used are described below.

In the first procedure, the borehole is advanced to the base of the first saturated zone. Casing is then anchored in the underlying impermeable layer (aquitard) by advancing the casing at least 1 foot into the aquitard and grouting to the surface. After the grout has cured, a smaller diameter borehole is drilled through the grout. This procedure is repeated until the zone of interest is reached. After the zone is reached, a conventional well screen and riser are set. A typical well constructed in this manner is shown on Figure 2.

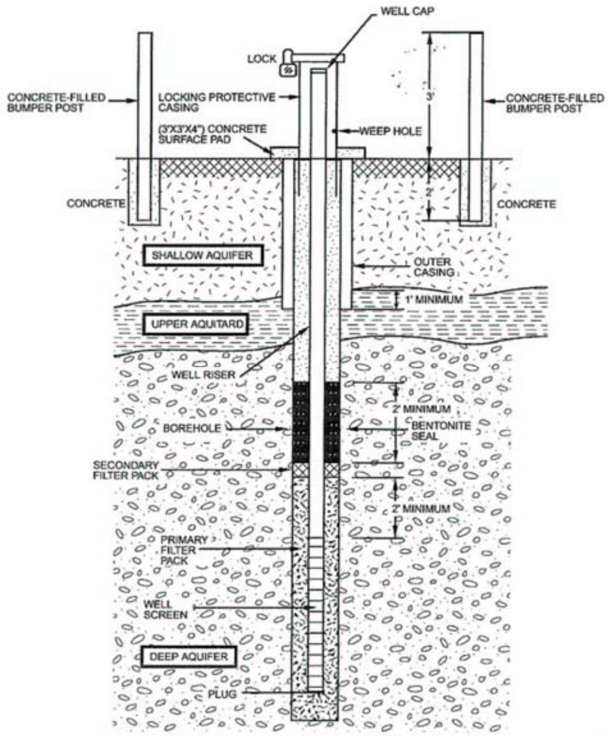


Figure 2 - Multiple Casing Well Completion Diagram

A second acceptable procedure involves driving a casing through several saturated layers while drilling ahead of the casing. However, this method is not acceptable when the driven casing may structurally damage a competent aquitard or aquiclude and result in cross-contamination of the two saturated layers. This method should also be avoided when highly contaminated groundwater or nonaqueous-phase contamination may be dragged down into underlying uncontaminated hydrologic units.

4.0 RECORDKEEPING PROCEDURES

Recordkeeping procedures associated with monitoring well installation are described in the following sections. These include procedures for surveying, obtaining permits, completing well construction records, and identifying monitoring wells.

4.1 SURVEYING

Latitude, longitude, and elevation at the top of the riser should be determined for each monitoring well. A permanent notch or black mark should be made on the north side of the riser. The top of the riser and ground surface should be surveyed.

4.2 PERMITS AND WELL CONSTRUCTION RECORDS

Local and state regulations should be reviewed prior to monitoring well installation, and any required well permits should be in-hand before the driller is scheduled.

Monitoring well installation activities should be documented in both the field logbook and on the Monitoring Well Completion Record (attached). Geologic logs should be completed and, if necessary, filed with the appropriate regulatory agency within the appropriate time frame.

4.3 MONITORING WELL IDENTIFICATION

Each monitoring well should have an individual well identification number or name. The well identification may be stamped in the metal surface upon completion or permanently marked by using another method. Current state and local regulations should be checked for identification requirements (such as township, range, section, or other identifiers in the well name).

DISCLAIMER
This SOP provided general guidance for TIMET contractors and subcontractors for technical issues addressed during environmental site investigation and remediation activities. It is noted, however, that each site and project is unique and these guidelines are not a substitute for common sense and good management practices based on professional training and experience. In addition, individual contract terms may affect the implementation of this SOP. TIMET contractors reserve the unrestricted right to change, modify or not apply these guidelines in their sole, complete, and unrestricted discretion to meet certain circumstances, contractual requirements, site conditions, or job requirements.

CHAPTER 534 - UNDERGROUND WATER AND WELLS
GENERAL PROVISIONS

LICENSE TO DRILL WELL

GENERAL PROVISIONS

NAC 534.010 Definitions. (NRS 534.020, 534.110) As used in this chapter, unless the context otherwise requires, the words and terms defined in NAC 534.015 to 534.240, inclusive, have the meanings ascribed to them in those sections.

(Supplied in codification; A by St. Engineer, 1-9-90; 12-30-97)

NAC 534.015 "Abandon" defined. (NRS 534.020, 534.110) "Abandon" means to discontinue the use of a well or borehole or to leave the well or borehole in such a state of disrepair that to use it would be impracticable, may result in contamination of ground water or may otherwise pose a hazard to the health or safety of the general public.

(Added to NAC by St. Engineer, eff. 1-9-90; A 12-30-97)

NAC 534.020 "Annular space" defined. (NRS 534.020, 534.110) "Annular space" means the space between two cylindrical objects, one of which surrounds the other, such as the space between the walls of the well bore and the casing.

[St. Engineer, Drilling Wells Reg. § 1.01, eff. 5-19-81]—(NAC A 1-9-90; 12-30-97)

NAC 534.030 "Aquifer" defined. "Aquifer" has the meaning ascribed to it in NRS 534.0105.
[St. Engineer, Drilling Wells Reg. § 1.02, eff. 5-19-81]—(NAC A 1-9-90)

NAC 534.040 "Artesian well" defined. "Artesian well" has the meaning ascribed to it in NRS 534.012.

[St. Engineer, Drilling Wells Reg. § 1.03, eff. 5-19-81]—(NAC A 1-9-90)

NAC 534.042 “Bentonite grout” defined. (NRS 534.020, 534.110) “Bentonite grout” means a product that is specifically designed to seal and plug wells and boreholes and:

1. Consists of not more than 87.9 percent water and not less than 12.1 percent bentonite by weight of water;
2. Has the ability to gel;
3. Does not separate into water and solid materials after it gels;
4. Has hydraulic conductivity or permeability values of 10-7centimeters per second or less; and
5. Has a fluid weight of not less than 9 pounds per gallon.
   (Added to NAC by St. Engineer, eff. 12-30-97)

NAC 534.043 “Blast hole” defined. (NRS 534.020, 534.110) “Blast hole” means a borehole that is drilled and, as soon as practicable, is loaded with explosives for mining purposes.
(Added to NAC by St. Engineer, eff. 12-30-97)

NAC 534.045 “Board” defined. “Board” means the statewide well drillers’ advisory board.
(Added to NAC by St. Engineer, eff. 1-9-90)

NAC 534.047 “Borehole” defined. (NRS 534.020, 534.110) “Borehole” means a penetration in the ground that is deeper than the longest dimension of its opening at the surface and is made to obtain geologic, hydrologic, geophysical or geotechnical information, to obtain information relating to engineering or for any other purpose other than for use as a well.
(Added to NAC by St. Engineer, eff. 12-30-97)

NAC 534.048 “Bridge” defined. (NRS 534.020, 534.110) “Bridge” means an obstruction in the well bore or annular space of a borehole or well caused when the walls of the well bore collapse or when materials are jammed or wedged into the well bore or annular space.
(Added to NAC by St. Engineer, eff. 12-30-97)

NAC 534.050 “Casing” defined. “Casing” means the conduit required to prevent waste and contamination of the ground water and to hold the formation open during the construction or use of the well.
[St. Engineer, Drilling Wells Reg. § 1.04, eff. 5-19-81]—(NAC A 1-9-90)

NAC 534.060 “Cement grout” defined. “Cement grout” means a mixture of Portland Cement, sand and water which contains at least seven bags of cement per cubic yard and not more than 7 gallons of clean water for each bag of cement (1 cubic foot or 94 pounds).
[St. Engineer, Drilling Wells Reg. § 1.14, eff. 5-19-81]—(NAC A 1-9-90)

NAC 534.070 “Concrete grout” defined. “Concrete grout” means a mixture of Portland Cement, sand, 1/4-inch minus aggregate and water which contains at least five bags of cement per cubic yard of concrete and not more than 7 gallons of clean water per bag of cement (1 cubic foot or 94 pounds).
[St. Engineer, Drilling Wells Reg. § 1.13, eff. 5-19-81]—(NAC A 1-9-90)

NAC 534.080 "Conductor casing" defined. (NRS 534.020, 534.110) "Conductor casing" means the temporary or permanent casing used in the upper portion of the well bore to prevent collapse of the formation during the construction of the well or to conduct the gravel pack to the perforated or screened areas in the casing.
[St. Engineer, Drilling Wells Reg. § 1.05, eff. 5-19-81]—(NAC A 1-9-90; 12-30-97)

NAC 534.094 "Contaminant" defined. (NRS 534.020, 534.110) "Contaminant" means any chemical, mineral, live organism, organic material, radioactive material or heated or cooled water that may adversely affect the quality of ground water.
(Added to NAC by St. Engineer, eff. 12-30-97)

NAC 534.095 "Contamination" defined. (NRS 534.020, 534.110) "Contamination" means the impairment of water quality by the introduction of contaminants into the ground water.
(Added to NAC by St. Engineer, eff. 1-9-90; A 12-30-97)

NAC 534.100 "Division" defined. "Division" means the division of water resources of the state department of conservation and natural resources.
[St. Engineer, Drilling Wells Reg. § 1.07, eff. 5-19-81]

NAC 534.110 "Domestic use" defined. "Domestic use" has the meaning ascribed to it NRS 534.013.
[St. Engineer, Drilling Wells Reg. § 1.08, eff. 5-19-81]—(NAC A 1-9-90)

NAC 534.112 "Drill rig" defined. (NRS 534.020, 534.110) "Drill rig" means any power-driven percussion, rotary, boring, coring, digging, jetting or augering machine used in the construction of a well or borehole.
(Added to NAC by St. Engineer, eff. 12-30-97)

NAC 534.113 "Drive point well" defined. (NRS 534.020, 534.110) "Drive point well" means a temporary monitoring well constructed by driving a drive point attached to the end of a section of pipe into the ground for the purpose of obtaining geotechnical or environmental information. The term is synonymous with a push point well.
(Added to NAC by St. Engineer, eff. 1-9-90; A 12-30-97)

NAC 534.120 "Exploratory well" defined. (NRS 534.020, 534.110) "Exploratory well" means a well constructed pursuant to paragraph (a) of subsection 2 of NRS 534.050 to determine the availability of water or whether an aquifer is capable of transmitting water to a well.
[St. Engineer, Drilling Wells Reg. § 1.09, eff. 5-19-81]—(NAC A 1-9-90; 12-30-97)

NAC 534.140 "Ground water" defined. (NRS 534.020, 534.110) "Ground water" means water below the surface of the land that is in a zone of saturation.
[St. Engineer, Drilling Wells Reg. § 1.11, eff. 5-19-81]—(NAC A 12-30-97)

NAC 534.148 "Monitoring well" defined. (NRS 534.020, 534.110) "Monitoring well" means any well that is constructed to evaluate, observe or determine the quality, quantity, temperature, pressure or other characteristic of ground water or an aquifer. The term includes an observation well, piezometer, drive point well or vapor extraction well.
(Added to NAC by St. Engineer, eff. 12-30-97)

NAC 534.150 "Neat cement" defined. (NRS 534.020, 534.110) "Neat cement" means a mixture of:

1. Clean water and cement in a ratio of not more than 5.2 gallons of water per bag of Portland Cement (1 cubic foot or 94 pounds); or
2. Clean water, cement and sodium bentonite in a ratio of not more than 7.8 gallons of water per 3.76 pounds of sodium bentonite by dry weight and one bag of Portland Cement (1 cubic foot or 94 pounds).

[St. Engineer, Drilling Wells Reg. § 1.12, eff. 5-19-81]—(NAC A 12-30-97)

NAC 534.160 "Nominal size" defined. "Nominal size" means the manufactured commercial designation of the diameter of a casing. An example would be casing with an outside diameter of 12 3/4 inches which may be nominally 12-inch casing by manufactured commercial designation.

[St. Engineer, Drilling Wells Reg. § 1.15, eff. 5-19-81]

NAC 534.165 "Observation well" defined. (NRS 534.020, 534.110) "Observation well" means a borehole in which a temporary casing has been set and which is used to observe, test and measure the elevation of the water table, the pressure variations within an aquifer and the movement of contaminants inside or outside a zone of saturation.

(Added to NAC by St. Engineer, eff. 12-30-97)

NAC 534.175 "Permit" defined. "Permit" means the written permission from the state engineer to appropriate public waters for a beneficial use from a surface or underground source, at a specific point of diversion, under limited circumstances.

(Added to NAC by St. Engineer, eff. 1-9-90)

NAC 534.179 "Piezometer" defined. (NRS 534.020, 534.110) "Piezometer" means a well that is constructed to measure water pressure or soil moisture tensions at one or more discrete intervals.

(Added to NAC by St. Engineer, eff. 12-30-97)

NAC 534.182 "Pitless adapter" defined. (NRS 534.020, 534.110) "Pitless adapter" means a commercially manufactured device designed for attachment to openings through the casing of a water well that permits water service pipes to pass through the wall or an extension of a casing and prevents the entry of contaminants into the well or water supply.

(Added to NAC by St. Engineer, eff. 1-9-90; A 12-30-97)

NAC 534.183 "Plug" defined. (NRS 534.020, 534.110) "Plug" means the procedure in which a well or borehole is sealed after it is abandoned.

(Added to NAC by St. Engineer, eff. 1-9-90; A 12-30-97)

NAC 534.185 "Public survey" defined. (NRS 534.020, 534.110) "Public survey" means the description of the location of land using the survey system of the United States Government and includes the 40-acre subdivision within a quarter-quarter section, quarter section, section, township and range.

(Added to NAC by St. Engineer, eff. 1-9-90; A 12-30-97)

NAC 534.188 "Reconditioning" defined. (NRS 534.020, 534.110) "Reconditioning" means the deepening, reaming, casing, recasing, perforating, reperforating, installing of liner pipe, packers and seals or any other significant change in the design or construction of a water well.

(Added to NAC by St. Engineer, eff. 1-9-90; A 12-30-97)

NAC 534.190 "Seal" defined. (NRS 534.020, 534.110) "Seal" means the watertight seal established in a borehole or the annular space between the well casings or a well casing and the well bore to prevent the inflow or vertical movement of surface water or shallow ground water, or to prevent the outflow or vertical movement of water under artesian pressures. The term includes a sanitary seal.

[St. Engineer, Drilling Wells Reg. § 1.19, eff. 5-19-81]—(NAC A 1-9-90; 12-30-97)

NAC 534.192 "Seismic shot hole" defined. (NRS 534.020, 534.110) "Seismic shot hole" means a borehole in which an explosion is detonated to assist studies of the geology of the earth.

(Added to NAC by St. Engineer, eff. 12-30-97)

NAC 534.194 "Sodium bentonite" defined. (NRS 534.020, 534.110) "Sodium bentonite" means a colloidal clay that:

1. Consists primarily of the mineral montmorillonite;
2. Has the ability to swell; and
3. May be mixed with water to form bentonite grout.

(Added to NAC by St. Engineer, eff. 12-30-97)

NAC 534.195 "Static water level" defined. (NRS 534.020, 534.110) "Static water level" means the stabilized level or elevation of the surface of the water in a well or borehole that is not being pumped and is not affected by the pumping of other wells or boreholes.

(Added to NAC by St. Engineer, eff. 1-9-90; A 12-30-97)

NAC 534.205 "Vapor extraction well" defined. (NRS 534.020, 534.110) "Vapor extraction well" means any well constructed to remove vapors that may contaminate the ground water.

(Added to NAC by St. Engineer, eff. 12-30-97)

NAC 534.210 "Waste" defined. "Waste" has the meaning ascribed to it in NRS 534.0165.

[St. Engineer, Drilling Wells Reg. § 1.21, eff. 5-19-81]—(NAC A 1-9-90)

NAC 534.220 "Well" defined. (NRS 534.020, 534.110) "Well" means a penetration in the ground made for the purpose of measuring, testing or sampling the underground strata or producing ground water. The term includes a water well, monitoring well or exploratory well.

[St. Engineer, Drilling Wells Reg. § 1.22, eff. 5-19-81]—(NAC A 1-9-90; 12-30-97)

NAC 534.235 "Well bore" defined. (NRS 534.020, 534.110) "Well bore" means a cylindrical hole made in the construction or drilling of a well.

(Added to NAC by St. Engineer, eff. 12-30-97)

NAC 534.240 "Well driller" defined. "Well driller" has the meaning ascribed to it in NRS 534.017.

[St. Engineer, Drilling Wells Reg. § 1.24, eff. 5-19-81]—(NAC A 1-9-90)

LICENSE TO DRILL WELL

NAC 534.280 Application for license or renewal of license. (NRS 534.020, 534.110)An application for a well-drilling license or the renewal of a well-drilling license must be submitted to the division. The application must be completed and accompanied by the fee prescribed in NRS 534.140.

[St. Engineer, Drilling Wells Reg. § 2.01, eff. 5-19-81]—(NAC A 1-9-90; 12-30-97)

NAC 534.282 Qualifications of applicant; denial of application. (NRS 534.020, 534.110)

1. An applicant for a well-drilling license must:
   (a) Demonstrate a good working knowledge of:
      (1) Standard drilling practice;
      (2) The regulations of the state engineer and applicable laws relating to the construction of wells; and
      (3) The method by which land is described by public survey.
         (b) Have at least 2 years of experience determined to be appropriate by the state engineer for the license for which the applicant applies.
         (c) Pass an examination, consisting of an oral portion and a written portion, conducted by the state engineer and the board.
2. The state engineer may deny an applicant a license if he:
   (a) Fails to notify the division that he cannot appear for the examination as instructed by a notice to appear before the state engineer or the board;
   (b) Has notified the division on three occasions that he cannot appear for the examination as instructed by a notice to appear before the state engineer or the board; or
   (c) Has failed any portion of the examination three times.
   (Added to NAC by St. Engineer, eff. 1-9-90; A 12-30-97)

NAC 534.286 Oral examination of applicants. (NRS 534.020, 534.110) Except as otherwise provided in NAC 534.288, the board shall conduct the oral portion of the examination for each applicant for a well-drilling license. The oral portion of the examination must be conducted to determine the sufficiency of the applicant's:

1. Knowledge of the provisions of chapter 534 of NRS and this chapter; and
2. Qualifications and experience.
   (Added to NAC by St. Engineer, eff. 1-9-90; A 12-30-97)

NAC 534.288 Board not required to conduct oral examination of certain applicants. (NRS 534.020, 534.110) The board is not required to conduct the oral portion of the examination for an applicant for a well-drilling license who:

1. Receives a score of less than 70 percent on the written portion of the examination; or
2. Is unable to demonstrate his ability to locate a well on a topographic map.
   (Added to NAC by St. Engineer, eff. 1-9-90; A 12-30-97)

NAC 534.290 Revocation or denial of license. (NRS 534.020, 534.110)

1. The state engineer may revoke or refuse to reissue a well-drilling license if he determines, after an investigation and a disciplinary hearing, that the well driller has:
   (a) Intentionally made a material misstatement of facts in his application for a license;

(b) Intentionally made a material misstatement of facts in a log or record of work;
(c) Been found to be incompetent as a well driller by the state engineer or the board;
(d) Failed to submit a log or record of work for wells drilled in accordance with the provisions of this chapter;
(e) Failed to comply with or violated any of the provisions of this chapter;
(f) Failed to comply with or violated any law applicable to well drillers;
(g) Falsely sworn to any affidavit, proof of completion, proof of beneficial use, log or any other document filed with the division;
(h) Supplied false information to an owner of a well or a holder of a permit or his agent; or
(i) Failed to report information concerning improper construction or the abandonment of a well pursuant to NAC 534.448.

2. The state engineer will avail himself of the services of the board pursuant to NRS 534.150 if he determines that to do so is appropriate under the circumstances.
[St. Engineer, Drilling Wells Reg. §§ 8.01 & 8.02, eff. 5-19-81]—(NAC A 1-9-90; 12-30-97)

NAC 534.292 Notice to renew license; notice of change in mailing address.

1. The division will mail to each licensed well driller a notice to renew his license approximately 30 days before the expiration of the license. Failure to receive the notice does not relieve a well driller of his obligation to pay the fee for renewal in a timely manner.
2. A well driller shall notify the division of any change in his mailing address within 30 days after the change.
(Added to NAC by St. Engineer, eff. 1-9-90)

NAC 534.293 Additional requirements for license if prior license has expired or been revoked. (NRS 534.020, 534.110)A well driller whose license has been expired for more than 1 year or whose license has been revoked:

1. Must file a new application with the fee required by NRS 534.140 to obtain a license.
2. Before resolving a complaint in his file, must appear before the board for disposition of the complaint.
3. May be required by the board to pass the examination required by NAC 534.282.
(Added to NAC by St. Engineer, eff. 1-9-90; A 12-30-97)

NAC 534.294 Scope of authority under license; issuance of restricted licenses. (NRS 534.020, 534.110)

1. A well-drilling license authorizes the licensee to drill, recondition or plug the following types of wells:
(a) Water wells;
(b) Monitoring wells; and
(c) Geothermal wells.
2. The state engineer may issue restricted well-drilling licenses that limit a well driller to a class of work or type of drilling rig, or both, for which the board has

determined the driller is qualified. The following restricted well-drilling licenses may be issued:

(a) A monitoring well-drilling license;
(b) A geothermal well-drilling license;
(c) A license to drill wells for projects of the Federal Government; and
(d) Any other class of well-drilling license determined to be appropriate by the board and the state engineer.

(Added to NAC by St. Engineer, eff. 1-9-90; A 12-30-97)

NAC 534.296 Issuance and expiration of temporary license; employment of prospective temporary licensee. (NRS 534.020, 534.110)

1. The state engineer may issue a temporary well-drilling license to an employee of a drilling contractor if the drilling contractor has insufficient personnel to complete existing contracts.
2. If the employee of a drilling contractor submits an application for a temporary license, the drilling contractor or an employee of the drilling contractor must:
   (a) Hold a well-drilling license issued by the state engineer; and
   (b) Sign and submit a letter to the division containing:
      (1) A request that the person named in the application be given a temporary license;
      (2) A statement from the contractor, the licensed employee of the contractor or another licensed well driller stating that the person who is making the statement will take full responsibility for the drilling performed by the prospective temporary licensee; and
      (3) A statement that the prospective temporary licensee will comply with all regulations for drilling wells.
3. The state engineer will evaluate the qualifications of the prospective temporary licensee and may issue a temporary license which expires on the date of the next available examination conducted by the board.
4. The drilling contractor shall inform the division in writing if the employment of the temporary licensee is terminated before the date of the next available examination. The contractor is responsible for any drilling performed by the temporary licensee until the notice of termination is received by the division. The notice of termination must explain the reasons for terminating the employment of the temporary licensee. The temporary license expires upon receipt of the notice by the division.

(Added to NAC by St. Engineer, eff. 1-9-90; A 12-30-97)

NAC 534.298 Temporary license: Period of validity; authorized activities; transferability. A temporary well-drilling license:

1. Is valid until the next scheduled examination administered by the board;
2. Authorizes well drilling to be performed only for the contractor who requested the license; and
3. Is not transferable.

(Added to NAC by St. Engineer, eff. 1-9-90)

DUTIES OF WELL DRILLERS

NAC 534.300 Designated basins; replacement wells. (NRS 534.020, 534.110)

1. Except as otherwise provided in NAC 534.315, a well driller shall not drill a water well within a ground water basin designated by the state engineer until the well driller determines that a permit to appropriate the ground water has been issued pursuant to NRS 534.050.
2. A water well may be drilled to replace an existing well if the existing well cannot be reconditioned and it will no longer produce the quantity of water allowed by the permit. A permit, waiver or certificate of water right must exist for the well to be replaced. The replacement well must not be drilled more than 300 feet from the location of the existing well described in the permit and may not be moved outside of the 40-acre subdivision described in the permit, waiver or certificate. The existing well must be plugged at the time the replacement well is drilled. If continued use will be made of the existing well, a permit or waiver must be issued for the replacement well before any drilling is commenced.
[St. Engineer, Drilling Wells Reg. §§ 10.01-10.03, 10.05 & 10.06, eff. 5-19-81]—(NAC A 1-9-90; 12-30-97)

NAC 534.310 Nondesignated basins. (NRS 534.020, 534.110)

1. Except as otherwise provided in NAC 534.315:
   (a) In basins which have not been designated by the state engineer, a person who drills a well before receiving a permit to appropriate water does so at the risk that a permit to appropriate water cannot be obtained; and
   (b) A person shall not use water from a well until a permit or waiver has been obtained pursuant to NRS 534.050.
2. In basins which have not been designated by the state engineer, the well driller may proceed to drill and perform tests on a well whether or not the owner of the property has a permit to appropriate water. The well driller shall submit to the state engineer a notice of intent to drill and a log and record of work as prescribed in NAC 534.340.
3. In basins which have not been designated by the state engineer, a waiver is required for any water well:
   (a) That does not comply with the requirements for construction prescribed in this chapter; or
   (b) The water appropriated from which will be used in constructing a highway or exploring for oil, gas, minerals or geothermal resources.
   [St. Engineer, Drilling Wells Reg. Part 11, eff. 5-19-81]—(NAC A 12-30-97)

NAC 534.315 Domestic wells. (NRS 534.020, 534.110)

1. Except as otherwise provided in subsection 8, permits to appropriate ground water are not required for the drilling of domestic wells.
2. A well driller shall take into account the normal annual fluctuations in the demand for water of an area and, if the well is in a developed area, some annual drop in static water level.
3. Water may not be diverted from more than one well for domestic use in one single-family residence.

4. A well drilled for domestic use only must have a casing size not larger than 8.625 inches in diameter.
5. If a domestic well cannot be reconditioned, a replacement may be drilled if the original well is plugged as required by NAC 534.420 as soon as practicable after the new well is drilled.
6. Except as otherwise provided in subsection 7, a well may be drilled for domestic use if not more than 1,800 gallons of water per day are diverted from the well for use by a single-family household, including a residence with a lawn, garden and domestic animals.
7. If water service is available from an entity such as a public utility, a water district or a municipality presently engaged in furnishing water to the inhabitants of the area, a domestic well may not be drilled, deepened, reconditioned or replaced.
8. A permit must be obtained from the division if:
   (a) More than 1,800 gallons of water per day are diverted from a water well; or
   (b) Water is diverted from the well for more than one single-family dwelling.
   [St. Engineer, Drilling Wells Reg. § 10.04 + Part 12, eff. 5-19-81]—(NAC A 1-9-90; 12-30-97)—(Substituted in revision for NAC 534.400)

NAC 534.320 Notice of intent to drill: Contents; submission. (NRS 534.020, 534.110)

1. A driller shall notify the division before drilling, reconditioning or plugging a well by submitting a notice of intent to drill. The notice must be submitted for work on an exploratory, water or monitoring well. A well driller shall notify the division before drilling a geothermal well if a permit to appropriate water is required pursuant to NRS 534.050.
2. The notice must give the name of the person for whom the work is being performed, the location of the well by public survey, the lot number, block number and county assessor's parcel number, the purpose of the well, the date on which the work is to be commenced, the type of work to be done and the diameter of casing to be installed. The notice must be signed by the well driller or contractor, and the license number of the driller who will be at the site and responsible for the work must be included.
3. The well driller shall submit to the division a notice of intent to drill. The notice must be received by the division at least 3 working days before the well rig is to be set up and the drilling commenced. If a permit or waiver is required for the drilling operation, the number of the permit or waiver issued by the division must be indicated on the notice of intent to drill in addition to the information required by subsection 2.
4. The forms evidencing notice of intent to drill will be furnished by the division to the driller on request and will be stamped and self-addressed.
5. If a well is to be drilled in a township that is located north of the Mount Diablo baseline, the notice of intent to drill must be submitted to the office of the division located in Carson City. If a well is to be drilled in a township which is located south of the Mount Diablo baseline, the notice of intent to drill must be submitted to the office of the division located in Las Vegas.
   [St. Engineer, Drilling Wells Reg. Part 4, eff. 5-19-81]—(NAC A 1-9-90; 12-30-97)

NAC 534.325 Notice of intent to drill: Lapse; submission of new notice. (NRS 534.020, 534.110)

1. If the well described on a notice of intent to drill is not drilled within 60 days after the division receives the notice, the notice lapses and a new notice must be submitted before the well is drilled. The new notice must include the number of the lapsed notice.
2. The well driller may set up the drill rig and commence drilling immediately after the division receives the new notice.
3. The well driller shall indicate on the record of work for the well the number of the notice of intent to drill that the driller last submitted for that well.
   (Added to NAC by St. Engineer, eff. 1-9-90; A 12-30-97)

NAC 534.330 Responsibilities of licensed well driller at drilling site. (NRS 534.020, 534.110) A well driller licensed by the state engineer:

1. Must be present at the well-drilling site when the drilling rig is in operation. If the licensed well driller leaves the drilling site, the drilling operation must be shut down until the driller or another well driller licensed pursuant to this chapter returns to the site.
2. Shall ensure that the drilling of the well complies with:
   (a) The provisions of this chapter;
   (b) The terms and conditions of any permit, waiver or order issued by the state engineer; and
   (c) The requirements of all other federal, state and local agencies which have jurisdiction over the land on which the well is to be drilled.
3. Shall carry his license card when he is present at the drilling site and produce the card when requested to do so by a representative of the division.
   [St. Engineer, Drilling Wells Reg. § 2.02, eff. 5-19-81]—(NAC A 1-9-90; 12-30-97)

NAC 534.340 Log and record of work: Form; contents. (NRS 534.020, 534.110)

1. A log and record of work submitted by a well driller pursuant to NRS 534.170 must be typewritten or legibly handwritten in black ink.
2. In addition to the information required pursuant to NRS 534.170, the following information must be contained in the record of work:
   (a) The complete name and address of the person for whom the work is being performed.
   (b) The location of the well, including:
   (1) A description of its location by public survey and county assessor's parcel number.
   (2) In a record of work for a domestic well, the address of the house to be served by the well, the lot and block description and the name of the subdivision.
   (3) If applicable, the waiver number or permit number.
   (c) If possible, the pressure head of the well and any pumping test or development data.
   (d) An accurate identification of the water-bearing formations.
   (e) If the static water level is measured from the top of the casing, the elevation of the top of the casing above the land surface.
3. An accurate description of the perforations in the casing must be set forth in the section of the record of work that contains a record of the well casing.

4. If the well driller does not have a thermometer, the temperature of the water may be described in the record of work as cold, warm or hot.
5. The flow from a well which flows or is pumped may be determined for the purpose of the record of work by measuring the length of time it takes to fill a container of known capacity if the flow is not too large to be measured in that manner.
6. As used in this section, “pumping test” means a test of a well conducted by pumping a specified amount or continuous flow of water from a well to determine the characteristics of the well or an aquifer.
   [St. Engineer, Drilling Wells Reg. Part 7, eff. 5-19-81]—(NAC A 1-9-90; 12-30-97)

NAC 534.345 Record of work: Completion; return for correction. (NRS 534.020, 534.110)
1. All work performed by the well driller during the drilling operation must be accurately described in the record of work submitted by the well driller pursuant to NRS 534.170 and NAC 534.340.
2. If any of the information required to be included by regulation or statute is omitted from the record of work, the division will return the record of work for correction.
   (Added to NAC by St. Engineer, eff. 1-9-90; A 12-30-97)

NAC 534.350 Identification of well rig. (NRS 534.020, 534.110) The name and address of the contractor drilling the well must be conspicuously displayed in legible letters at least 3 inches high on the drill rig operated or owned by that contractor. The identification must be displayed on the rig before the rig is positioned at the drill site.
[St. Engineer, Drilling Wells Reg. Part 9, eff. 5-19-81]—(NAC A 1-9-90; 12-30-97)

NAC 534.355 Reporting of unauthorized activities. (NRS 534.020, 534.110) A licensed well driller who becomes aware of specific information relating to improper construction or the abandonment of a well shall report that information to the division as soon as practicable.
(Added to NAC by St. Engineer, eff. 12-30-97)

DRILLING, CONSTRUCTION AND PLUGGING OF WELLS AND BOREHOLES

NAC 534.360 Construction of well: Casing. (NRS 534.020, 534.110)
1. Except as otherwise provided in subsection 2, all wells must be cased to the bottom of the well bore and constructed to prevent contamination or waste of the ground water.
2. If no additional water is developed in the bottom portion of a well, neat cement, cement grout or concrete grout must be placed by tremie pipe in an upward direction from the bottom of the well to the bottom of the casing.
3. The casing must:
   (a) Except as otherwise provided in this paragraph and NAC 534.362, be of new steel or clean and sanitary used steel. Materials other than steel may be used if the design of the well or the subsurface conditions prevent the use of steel casing and a professional engineer who holds a certificate of registration issued pursuant to chapter 625 of NRS has approved the casing materials.
   (b) Be free of pits and breaks.

(c) Conform to the following minimum specifications, allowing for mill tolerance:
(1) If the conductor casing is 50 feet or less in depth, the thickness of the wall must be:
(I) At least 0.141 or 9/64 of an inch if the wall is made of a material other than galvanized steel pipe that has been corrugated; or
(II) At least 0.109 or 7/64 of an inch if the wall is made of galvanized steel pipe that has been corrugated.
(2) If the depth of the conductor casing exceeds 50 feet, and for all production or intermediate casing, the wall must be sufficiently thick to conform to the casing sizes listed in sub-subparagraphs (I) to (IV), inclusive:
(I) If the casing is smaller than 10 inches nominal size, the wall must be at least 0.188 or 3/16 of an inch thick.
(II) For 10-, 12-, 14- and 16-inch nominal size casing, the wall must be at least 0.250 or 1/4 of an inch thick.
(III) For 18- and 20-inch nominal size casing, the wall must be at least 0.312 or 5/16 of an inch thick.
(IV) For casing larger than 20 inches nominal size, the wall must be at least 0.375 or 3/8 of an inch thick.

4. The top of the casing on all wells must be at least 12 inches above the surface of the ground or the finished grade.
5. All production casing joints must be threaded and coupled or welded and be watertight. If the casing joints are welded, each joint must be welded completely. Spot welds of casing joints are prohibited.
6. The well driller shall ensure that the integrity of any casing to be used in the construction of the well has not been impaired by storage, shipping, handling or exposure to ultraviolet light.
[St. Engineer, Drilling Wells Reg. § 3.01, eff. 5-19-81]—(NAC A 1-9-90; 12-30-97)

NAC 534.362 Construction of well: Thermoplastic casing. (NRS 534.020, 534.110)
1. New thermoplastic water well casing made of polyvinyl chloride may be used as casing in a well if the casing:
(a) Is clearly marked as well casing; and
(b) Complies with the standards adopted by the American Society for Testing and Materials, designated as ASTM F-480, which are hereby incorporated by reference. A copy of the standards may be obtained from the American Society for Testing and Materials, 1916 Race Street, Philadelphia, Pennsylvania 19103, at a cost of $23 if prepaid, or $24.61 if not prepaid.
2. If polyvinyl chloride casing is used, the joint connections must be:
(a) Flush-threaded;
(b) Threaded and coupled; or
(c) Joined with nonmetallic couplings that are sealed with elastomeric sealing gaskets and which consist of flexible thermoplastic splines that are inserted into precisely machined grooves in the casing.

The joint connections must not be glued or joined by restraining devices that clamp into or otherwise damage the surface of the casing. If the joint connections are flush-threaded or threaded and coupled, the well driller shall ensure that the connections are not over-tightened.

3. If polyvinyl chloride casing is used in a water well or monitoring well, the well driller shall set a protective steel casing which complies with the provisions of NAC 534.360 and extends not less than 5 feet inside the sanitary seal and not less than 1 foot above the finished grade. The top of the protective casing must be fitted with a locking cap or a standard sanitary well cap.
(Added to NAC by St. Engineer, eff. 12-30-97)

NAC 534.370 Construction of well: Prevention of contamination; securing against unauthorized entry; suspension of drilling. (NRS 534.020, 534.110)

1. The driller shall take the precautions necessary to:
   (a) Seal off any known zones of poor quality water which may affect the zones of good quality water in the well.
   (b) Prevent contamination or waste of ground water.
2. Any additive used in drilling a well must be safe and must not contaminate or induce contamination of the ground water.
3. If it becomes necessary for the driller to discontinue the drilling operation before completion of the well, the well must be covered securely to prevent a contaminant from entering the casing or borehole and rendered secure against entry by children, domestic animals and wildlife.
4. After drilling is completed, all openings must be closed off to prevent contamination of the well. A sanitary well cap or welded plate must be welded to the well.
5. If drilling is suspended for any reason, the division must be notified within 24 hours after drilling is suspended or before the drilling equipment is moved from the drilling site, whichever occurs first. The suspension of drilling without completing or plugging the well must be approved by the division.
[St. Engineer, Drilling Wells Reg. §§ 3.14 & 3.15, eff. 5-19-81]—(NAC A 1-9-90; 12-30-97)

NAC 534.375 Construction of well: Measures required if contaminant or contaminated water is encountered. (NRS 534.020, 534.110) If a contaminant or contaminated water is encountered during the construction of a well, the strata which contain the contaminant or contaminated water must be cased or sealed in such a manner that the contaminant or contaminated water does not commingle with or impair other strata or the water contained in other strata. The well driller shall, by grouting or by using special seals or packers, prevent the movement of the contaminant or contaminated water in the well bore.
(Added to NAC by St. Engineer, eff. 12-30-97)

NAC 534.378 Construction of well: Measures required if artesian condition is encountered. (NRS 534.020, 534.110)

1. If an artesian condition is encountered in a well, the well driller shall, in addition to complying with the provisions of subsections 2 and 3 of NRS 534.060, ensure that unperforated casing extends through the confining strata above the artesian zone. The annular space between the casing and the walls of the well bore must be sealed by placing neat cement, cement grout or bentonite grout, that consists

of not less than 30 percent bentonite, by tremie pipe in an upward direction from the top of the artesian zone to the level necessary to prevent the leakage of artesian water above or below the surface.

2. Any flow of artesian water must be stopped completely before the drill rig is removed from the drill site.
(Added to NAC by St. Engineer, eff. 12-30-97)

NAC 534.380 Construction of well: Seals. (NRS 534.020, 534.110)

1. Before the drill rig is removed from the drill site of a well, the annular space between the well bore and the casing must be sealed by:
   (a) Placing neat cement, cement grout, concrete grout or bentonite grout, which consists of not less than 30 percent bentonite, from the sealing depth to 10 feet from the surface; and
   (b) Placing neat cement, cement grout or concrete grout from 10 feet below the surface to the surface.
2. The casing must be centered as nearly as practicable in the well bore to allow the sanitary seal to surround the casing.
3. If a temporary conductor casing is used, it must be withdrawn during the placement of the grout.
4. If a pitless adapter is used in domestic or small commercial wells:
   (a) The sanitary seal must begin not more than 5 feet below ground level;
   (b) The sanitary seal must extend at least 50 feet below ground level; and
   (c) The portion of the casing above the sanitary seal must be backfilled to ground level with uncontaminated soil which is compacted.
5. A pipe used to feed gravel through the cement seal or to provide access to the interior of the well must be fitted with a watertight cap.
6. A licensed driller must place the seal or directly supervise the placement of the seal.
7. The seal must be placed:
   (a) In the annular space within 3 days after the casing is set and before the drill rig is removed from the drill site.
   (b) In one continuous mass or completed within 24 hours.
   (c) By tremie pipe in an upward direction to displace the fluid to the surface of the ground, if any fluid is standing in the well bore above the sealing depth.
8. The diameter of the well bore must be at least 4 inches larger than the diameter of the outside of the outermost casing to be used. If a fill pipe for gravel is installed, the diameter of the well bore must be 4 inches larger than the diameter of the casing plus the diameter of the fill pipe for gravel. A fill pipe for gravel or any other pipe to provide access to the interior of the well must be completely surrounded by the seal. A conductor casing may be used to convey the gravel pack. If a conductor casing is used:
   (a) The diameter of the well bore must be at least 4 inches larger than the diameter of the conductor casing; and
   (b) The annular space between the conductor casing and the well bore must be sealed.
9. A watertight seal must be installed at the surface level between the conductor casing and the production casing to prevent any contaminants from entering the gravel pack conductor area. A welded plate or concrete seal must be used. If a

welded plate is used, the entire length of the plate must be welded to the conductor casing and production casing.
[St. Engineer, Drilling Wells Reg. §§ 3.02-3.13 & 3.16, eff. 5-19-81]—(NAC A 1-9-90; 12-30-97)

NAC 534.390 Construction of well: Location near river, lake, perennial stream, unlined reservoir or unlined canal; compliance with permit or waiver. (NRS 534.020, 534.110)

1. If a well, other than a monitoring well, is drilled within 1/4 mile of a river, lake, perennial stream, unlined reservoir or unlined canal:
   (a) Perforations in the production casing are prohibited from ground level to a depth of 100 feet.
   (b) The well must be sealed to a depth of 100 feet.
   (c) A permanent conductor casing may be used to convey the gravel pack to the 100-foot level.
2. If a well is being drilled pursuant to a permit or waiver, the well driller is responsible for satisfying the terms and conditions of the permit or waiver concerning the construction of the well.
   [St. Engineer, Drilling Wells Reg. Part 5, eff. 5-19-81]—(NAC A 1-9-90; 12-30-97)

NAC 534.420 Plugging of well: General requirements. (NRS 534.020, 534.110)

1. Except as otherwise provided in NAC 534.422, wells must be plugged in the manner prescribed in this section by a driller licensed by the state engineer.
2. A driller shall:
   (a) Ensure that a notice of his intent to plug a water well is received by the division not less than 3 working days before the drill rig is moved to the location where the well will be plugged; and
   (b) Notify the division not less than 24 hours before he begins to plug the well.
3. Before the driller begins to plug the well, he shall, if possible, obtain the log and record of work for that well from the division or the owner of the well.
4. On abandonment or order of the state engineer, a water well must be plugged by:
   (a) Removing the pump or debris from the well bore with appropriate equipment; and
   (b) If an annular cement seal was not installed, breaking the casing free with appropriate equipment so that the casing may be pulled from the well.
5. If the casing in the well:
   (a) Breaks free, the driller shall plug the borehole in the manner prescribed in NAC 534.4371 as the casing is pulled from the well or after the casing is removed from the well if the borehole remains intact. The well must be plugged from the total depth of the well to the surface of the well, in stages if necessary, to displace in an upward direction any fluid or debris in the well.
   (b) Does not break free, the driller shall perforate that portion of the casing which extends from the bottom of the well to not less than 50 feet above the top of the uppermost saturated ground water stratum. That portion of the casing must be perforated not less than four times per linear foot to allow the plugging fluid to penetrate the annular space and the geologic formation. The perforations made in each linear foot of the casing must

be made along a horizontal plane of the well bore. The angle between any two consecutive perforations made on a horizontal plane must not exceed 90 degrees, as measured from the center of the well bore. A well with a diameter of more than 8 inches in nominal size must be perforated a sufficient number of additional times per linear foot to ensure that the plugging fluid penetrates into the annular space and formation. The well driller shall then plug the well from the total depth of the well to 50 feet above the uppermost saturated ground water stratum or to within 20 feet of the surface of the well, whichever is less, with neat cement or bentonite grout specifically designed to plug abandoned wells.

6. The well driller shall place a surface plug in the well consisting of neat cement, cement grout or concrete grout, from a depth of at least 20 feet to the surface.
7. If the well casing does not break free and there is no evidence of a sanitary seal around the well casing, the driller shall, in addition to the requirements of subsection 5, perforate the upper 50 feet of casing before setting the surface plug. The casing must have at least four perforations per linear foot of casing and the surface plug must consist of neat cement.
8. A well driller shall submit a written report to the division within 30 days after a water well has been plugged. The report must contain the location of the well by public survey and county assessor's parcel number, the name of the owner of the well, the condition of the well, the static water level before plugging and a detailed description of the method of plugging, including, but not limited to:
   (a) The depth of the well;
   (b) The depth to which the materials used to plug the well were placed;
   (c) The type, size and location of the perforations which were made in the casing;
   (d) The debris encountered in, milled out of or retrieved from the well; and
   (e) The materials used to plug the well.
9. If there is any standing liquid in the interval of the well bore that is being plugged, all grout materials used pursuant to this section must be placed by tremie pipe in an upward direction.
   [St. Engineer, Drilling Wells Reg. Part 14, eff. 5-19-81]—(NAC A 1-9-90; 12-30-97)

NAC 534.422 Plugging of well: Use of exceptional method. (NRS 534.020, 534.110)

1. A well driller who wishes to plug a well in a manner that does not comply with the provisions set forth in NAC 534.420 must request approval from the division.
2. If the division authorizes the well driller to plug the well in a manner other than the manner set forth in NAC 534.420, the well driller shall comply with the instructions he receives from the division, if any, relating to the manner in which the well must be plugged.

(Added to NAC by St. Engineer, eff. 12-30-97)

NAC 534.424 Plugging of well: Responsibility for cost. (NRS 534.020, 534.110)

1. If a well is located on private land, the owner of the land at the time the well is plugged is responsible for the cost of plugging the well.
2. If a well is located on public land, the person who last drilled or used the well is responsible for the cost of plugging the well. If the person who last drilled or used the well does not plug the well within 1 year after receiving notice from the

division by certified mail, return receipt requested, that the well must be plugged, the person who owns the land on which the well is located must plug the well.
(Added to NAC by St. Engineer, eff. 12-30-97)

NAC 534.427 Mandatory plugging of certain wells. (NRS 534.020, 534.110)

1. If any type of permit, waiver or application to appropriate water from a water well is canceled, abrogated, forfeited, withdrawn or denied, the well must be plugged in the manner prescribed in NAC 534.420.
2. A well, other than a water well drilled for a domestic purpose, for which a permit or waiver has not been issued must also be plugged in the manner prescribed in NAC 534.420.

(Added to NAC by St. Engineer, eff. 1-9-90; A 12-30-97)

NAC 534.430 Access port or removable well cap required. (NRS 534.020, 534.110)

1. Except as otherwise provided in subsection 3, each well that is drilled, deepened or reconditioned must have:
   (a) An access port near the top of the casing that is not less than 1 inch in diameter; or
   (b) A commercially manufactured sanitary well cap that may be easily removed to determine the level of water in the well.
2. An access port must have a watertight, screw-type cap seal to prevent contamination and must be kept closed.
3. On wells that are 8 inches in diameter or smaller, the access may be a 1/2-inch hole at the top of the casing or in the casing cover with a removable plug or bolt.
4. As used in this section, "access port" means an opening in the top of a well casing in the form of a tapped hole and plug or a capped pipe welded on the casing to permit entry of a device to measure the water level of the well.

[St. Engineer, Drilling Wells Reg. Part 6, eff. 5-19-81]—(NAC A 1-9-90; 12-30-97)

NAC 534.432 Noncompliance with requirements for well drilling. (NRS 534.020, 534.110) If a well was:

1. Constructed by a person who, at the time the well was constructed, was not the holder of a well-drilling license issued pursuant to NRS 534.140; or
2. Not constructed or completed in compliance with the provisions of this chapter as determined by the state engineer, the well must be abandoned and plugged in the manner prescribed in NAC 534.420.

(Added to NAC by St. Engineer, eff. 12-30-97)

NAC 534.4351 Monitoring wells: Restrictions on construction; submission of plat map and record of work. (NRS 534.020, 534.110)

1. A monitoring well must be:
   (a) Drilled only by a well driller who is licensed by the state engineer;
   (b) Constructed in accordance with the provisions of this chapter, except for any provision that is waived by the state engineer; and
   (c) Drilled only for the purpose of complying with federal, state or local environmental requirements or any other federal, state or local requirements.

2. A plat map showing the actual location of the monitoring well and a record of work which contains the information described in NRS 534.170 and NAC 534.340 must be submitted within 30 days after completion of the well by the person who is responsible for the well. The plat map must indicate the distance of the well from permanent reference points, including streets, roads or section lines. The map must be drawn on paper measuring 8 1/2 inches by 11 inches or 11 inches by 17 inches.

(Added to NAC by St. Engineer, eff. 12-30-97)

NAC 534.4353 Monitoring wells: Responsibilities of owner; permits; affidavit of responsibility for plugging. (NRS 534.020, 534.110)

1. The owner of a monitoring well shall ensure that the well:
   (a) Does not cause contamination of ground water during its use; and
   (b) Is plugged upon abandonment.
2. A permit to appropriate water or a waiver from the state engineer is not required to drill and collect data from a monitoring well unless the well is not constructed in the manner prescribed in this chapter.
3. The well driller shall, when he submits the notice of intent to drill pursuant to NAC 534.320, submit to the division a notarized affidavit on a form prescribed by the division which is signed by the person who will be responsible for plugging the well and states that he will be responsible for plugging the well when it is abandoned. The division shall prescribe the form required pursuant to this subsection and make copies of the form available upon request.
4. The owner of a monitoring well shall notify the division in writing as soon as practicable after determining that the well will no longer be used.
5. If a monitoring well or any other well is to be used to remove a contaminant from ground water, a permit to appropriate water for environmental purposes must be obtained from the state engineer pursuant to the provisions of NRS 533.437 to 533.4377, inclusive.

(Added to NAC by St. Engineer, eff. 12-30-97)

NAC 534.4355 Monitoring wells: Casing; prevention of contamination. (NRS 534.020, 534.110)

1. A well driller shall install casing in a monitoring well. If polyvinyl chloride casing is used, it must comply with the standards adopted by the American Society for Testing and Materials, designated as ASTM F-480.
2. The well driller shall take the precautions necessary to prevent contamination of ground water. The equipment used to construct a monitoring well must be decontaminated before the construction of the well is commenced.
3. The diameter of the casing must not exceed 4 inches in nominal size.
4. The connections of the casing must comply with the provisions of NAC 534.360 or 534.362. The connections must be made watertight by wrapping them with teflon tape, placing a ring or gasket between them or by any other method which will not introduce contaminants into the well.
5. Both ends of the casing must be capped.
6. The perforations must be of a width and length which will allow the strata to be observed while not permitting the infiltration of the gravel pack through the casing or allowing the contaminants or water from separate strata to commingle.

7. To ensure adequate space for the gravel pack and seals, the well bore of a monitoring well must, for the entire length of the casing placed in the well, be not less than 4 inches larger than the diameter of the casing.
8. Not more than one perforated or screened section of casing may be placed in the well bore of a monitoring well unless the vertical intervals of the well bore in between the screened sections are sealed with neat cement, cement grout, bentonite grout or fully hydrated sodium bentonite tablets or chips.
9. Not more than one casing may be placed in the well bore of a monitoring well unless the vertical intervals of the well bore in between the screened sections of the casings are sealed with neat cement, cement grout, bentonite grout or fully hydrated sodium bentonite tablets or chips.
10. Monitoring wells must be drilled an adequate distance from each other to ensure that there is no commingling of the contaminants or ground water encountered in the wells.

(Added to NAC by St. Engineer, eff. 12-30-97)

NAC 534.4357 Monitoring wells: Placement of gravel and seals in annular space. (NRS 534.020, 534.110)

1. If the water or vapors which are being monitored in a monitoring well are not encountered within 5 feet below the surface of the ground, the well driller shall place in the annular space of the well:
   (a) From the bottom of the well to 2 feet above the uppermost perforation in the casing, a gravel pack which consists of quartz sand, silica or other materials which will not contaminate the ground water or the geologic formation;
   (b) From the gravel pack placed pursuant to paragraph (a) to 2 feet above that gravel pack, a seal consisting of fully hydrated sodium bentonite pellets or bentonite grout; and
   (c) From the seal placed pursuant to paragraph (b) to the surface, a seal consisting of cement grout, neat cement, concrete or bentonite grout.
2. If the water or vapors which are being monitored in a monitoring well are encountered within 5 feet below the surface of the ground, the well driller shall comply with the requirements of subsection 1, except that:
   (a) The gravel pack required pursuant to paragraph (a) of subsection 1 must extend only 6 inches above the uppermost perforation in the casing; and
   (b) The surface seal required pursuant to paragraph (c) of subsection 1 must be placed from 1 foot below the surface to the surface.
3. The well driller shall ensure that a bridge does not occur in the annular space during the placement of the gravel pack and seals required pursuant to this section.
4. If more than 20 continuous feet of grout are placed in the annular space of the well or if there is standing liquid in the well bore above the sealing depth, the grout must be placed by tremie pipe in an upward direction.

(Added to NAC by St. Engineer, eff. 12-30-97)

NAC 534.4359 Monitoring wells: Measures required if contaminant or contaminated water is encountered. (NRS 534.020, 534.110) If a contaminant or contaminated water is encountered during the construction of a monitoring well, the strata which contain the contaminant or contaminated water must be cased and sealed in such a manner that the contaminant or contaminated water does not commingle with or impair other strata or the water contained in other strata. The well driller shall seal the strata by grouting or by using special seals or packers, if necessary, to prevent the movement of the contaminants or contaminated water in the well bore.

(Added to NAC by St. Engineer, eff. 12-30-97)

NAC 534.4361 Monitoring wells: Surface pad; prevention of unauthorized use; additional protective measures. (NRS 534.020, 534.110)

1. Unless the area surrounding a monitoring well is paved with concrete or asphalt, a surface pad must be installed around the casing at the surface.
2. A threaded or flanged cap or compression seal must be installed to prevent unauthorized use of the well. If the top of the well is flush with the surface and the well protector required pursuant to subsection 3 is of a type which may not be locked, the cap or seal must be of a type which may be locked.
3. The well must also be protected and secured by:
    (a) If it is not necessary for the well to be flush with the surface:
        (1) Setting a steel surface casing which complies with the requirements set forth in NAC 534.360 and extends not less than 5 feet below the surface pad and not less than 1 foot above the surface pad;
        (2) Fitting the top of the steel casing with a locking cap; and
        (3) Clearly marking the well as a monitoring well; or
    (b) If it is necessary for the well to be flush with the surface:
        (1) Placing a well protector capable of supporting vehicular travel which extends one-half inch above the surface pad or concrete or asphalt paving; and
        (2) Clearly marking the well as a monitoring well.
4. As used in this section, “surface pad” means a formation of concrete or cement grout with a diameter of not less than 1 foot and a thickness of not less than 3 1/2 inches which is set around a monitoring well at a slope to ensure that water flows away from the well.

(Added to NAC by St. Engineer, eff. 12-30-97)

NAC 534.4363 Monitoring wells: Artesian conditions. (NRS 534.020, 534.110) If an artesian condition is encountered in a monitoring well, the well driller shall ensure that the well is sealed in the manner prescribed in NAC 534.378.

(Added to NAC by St. Engineer, eff. 12-30-97)

NAC 534.4365 Monitoring wells: Plugging. (NRS 534.020, 534.110)

1. Except as otherwise provided in this section, a monitoring well must be plugged in the manner prescribed in NAC 534.420 within 3 days after it is abandoned.
2. Except as otherwise provided in subsections 3 and 4, a monitoring well may be plugged by:
    (a) Placing neat cement or a high-solids bentonite grout, which consists of not less than 20 percent bentonite, by tremie pipe in an upward direction from the bottom of the well to the surface; or
    (b) Placing sodium bentonite pellets or granules or bentonite grout from the bottom of the well to 20 feet below the surface and placing neat cement from 20 feet below the surface to the surface. Sodium bentonite pellets or

granules may not be placed in more than 100 feet of standing liquid unless the pellets or granules have been coated by the manufacturer to delay hydration.

3. The casing in the monitoring well must be removed from the well bore if:
   (a) The soil or water in the well is contaminated;
   (b) The well was not constructed pursuant to the provisions of this chapter; or
   (c) The well was constructed by a person who is not a licensed well driller. Except as otherwise provided in subsection 4, neat cement or high-solids bentonite grout must be placed by tremie pipe in an upward direction from the bottom of the well to the surface as the casing is removed from the well bore.
4. If the integrity of the borehole remains intact as the casing is removed from the well bore, the well may be plugged as provided in NAC 534.4371.

(Added to NAC by St. Engineer, eff. 12-30-97)

NAC 534.4367 Drive point wells. (NRS 534.020, 534.110)

1. A well driller may construct a drive point well without placing in the annular space of the well the gravel pack and seals required pursuant to NAC 534.4357.
2. The diameter of the casing used in a drive point well which is not constructed pursuant to the provisions of NAC 534.4357 must not be larger than 2 inches in nominal size.
3. A drive point well which is not constructed pursuant to the provisions of NAC 534.4357 must be abandoned within 60 days after the well is constructed. Upon abandonment, the casing must be removed from the well bore and the well bore must be plugged in the manner provided in NAC 534.4371.

(Added to NAC by St. Engineer, eff. 12-30-97)

NAC 534.4369 Boreholes: Generally. (NRS 534.020, 534.110)

1. A borehole may be drilled or plugged by a person who is not a licensed well driller.
2. A person who constructs a borehole is not required to file with the division a notice of intent to drill or plug the borehole.
3. A borehole may be drilled without obtaining from the division a permit to appropriate water or a waiver of the requirement to obtain such a permit.
4. A person who drills or plugs a borehole, the operator of the exploration project or the owner of the land where the borehole is located must maintain a record of the drilling operation which includes:
   (a) The dates on which the borehole is constructed and plugged;
   (b) The location of the borehole as shown by public survey;
   (c) The depth and diameter of the borehole;
   (d) The depth at which ground water is encountered in the borehole; and
   (e) The methods and materials used to plug the borehole.
5. The state engineer may, at any time, require the person drilling or plugging the borehole, the operator of the exploration project or the owner of the land on which the borehole is located to submit to the state engineer a copy of the record required pursuant to subsection 4 and any other information relating to the construction, operation or plugging of the borehole that the state engineer determines is necessary.

6. The owner and the lessor of the land on which a borehole is located, the operator of the exploration project and the drilling or plugging contractor for the project shall ensure that the ground water is uncontaminated during the drilling, operation or plugging of the borehole.

   (Added to NAC by St. Engineer, eff. 12-30-97)

NAC 534.4371 Boreholes: Plugging requirements; measures required if contaminant or contaminated water is encountered. (NRS 534.020, 534.110)

1. A borehole must be plugged within 60 days after it is drilled.
2. Except as otherwise provided in subsections 3 and 4, a borehole must be plugged:
   (a) In the manner prescribed in NAC 534.420;
   (b) If the highest saturated stratum is not more than 60 feet above the bottom of the borehole, by placing concrete grout, cement grout, neat cement or bentonite grout by tremie pipe in an upward direction from the bottom of the borehole to the surface or by placing sodium bentonite chips or pellets specifically designed to be used to plug boreholes from the bottom of the borehole to the surface; or
   (c) If the highest saturated stratum encountered in the borehole is more than 60 feet above the bottom of the borehole, by:
      (1) Plugging the portion of the borehole from the bottom to 50 feet above the highest saturated stratum encountered in the borehole in the manner described in paragraph (a);
      (2) Backfilling the portion of the borehole that extends from the materials placed in the borehole pursuant to subparagraph (1) to 10 feet from the surface with compacted soil which is uncontaminated; and
      (3) Placing any of the materials described in paragraph (a) from 10 feet below the surface to the surface.
3. If a contaminant or contaminated water is encountered in a borehole, the strata that contain the contaminant or contaminated water must be sealed in the manner prescribed in subsection 2 to prevent the contaminant or contaminated water from commingling with other strata or the water contained in other strata. The vertical movement of contaminants in the well bore must be prevented.
4. If the elevation of the bottom of the borehole is more than 50 feet above the preexisting natural elevation of any saturated ground water stratum, the borehole must be plugged by:
   (a) Backfilling the borehole from the bottom to 10 feet from the surface with compacted soil which is uncontaminated; and
   (b) Placing any of the materials described in paragraph (b) of subsection 2 from 10 feet below the surface to the surface.
5. If bentonite grout is used to plug a borehole, it must be mixed pursuant to the specifications recommended by the manufacturer.
6. If sodium bentonite chips or pellets or uncontaminated soil are placed in the borehole, they must be placed in such a manner that a bridge does not occur. Sodium bentonite chips or pellets may not be placed in more than 100 feet of standing liquid unless the chips or pellets have been coated by the manufacturer to delay hydration.
7. If casing is set in a borehole, the borehole must be completed as a well pursuant to the provisions of this chapter. The borehole must be plugged pursuant to NAC

534.420, or the casing must be removed from the borehole when it is plugged. The upper portion of the borehole may be permanently cased if the annular space between the casing and the walls of the borehole is completely sealed from the bottom of the casing to the surface pursuant to NAC 534.380.

(Added to NAC by St. Engineer, eff. 12-30-97)

NAC 534.4373 Boreholes: Responsibility for plugging. (NRS 534.020, 534.110) The owner and lessor of the land on which a borehole is located, the operator of the exploration project and the plugging contractor for the project are jointly and severally responsible for plugging the borehole pursuant to this chapter.

(Added to NAC by St. Engineer, eff. 12-30-97)

NAC 534.4375 Boreholes, blast holes and seismic shot holes: Artesian conditions. (NRS 534.020, 534.110) If an artesian condition is encountered in any borehole, blast hole or seismic shot hole, the artesian water strata must be contained pursuant to NRS 534.060 and NAC 534.378, and the borehole, blast hole or seismic shot hole must be sealed by the method described in subsection 2 of NAC 534.4371. The owner and lessor of the land on which a borehole is located, the operator of the exploration project and the drilling contractor for the project shall take the necessary steps to prevent the loss of water above or below the surface and to prevent the vertical movement of water in the well bore.

(Added to NAC by St. Engineer, eff. 12-30-97)

NAC 534.4377 Treatment of certain holes as boreholes. (NRS 534.020, 534.110)

1. For the purposes of this chapter, blast holes are not boreholes.
2. If the construction of a shot hole or a hole used for the installation of electrical conductors as part of a system to prevent corrosion or provide electrical grounding may cause waste or contamination of the ground water, the hole shall be deemed a borehole for the purposes of NAC 534.4369 and 534.4371.

   (Added to NAC by St. Engineer, eff. 12-30-97)

WAIVERS

NAC 534.440 Waiver to drill exploratory well to determine quality or quantity of water in designated basin. (NRS 534.020, 534.110)

1. The request for a waiver to drill an exploratory well to determine the quality or quantity of water pursuant to NRS 534.050 in a designated basin must be submitted in writing and contain the following information:
   (a) The location by public survey, county assessor's parcel number and plat map of the exploratory well anticipated to be drilled;
   (b) The name, address and telephone number of the person who:
       (1) Is collecting data from the exploratory well; and
       (2) Will be available to answer questions concerning the well;
   (c) The reason for requesting a waiver;
   (d) The proposed diameter and depth of the exploratory well;
   (e) The estimated starting and completion dates of the exploratory well, not to exceed 90 days after authority is given to drill;
   (f) The name, address and telephone number of the person who will be responsible for plugging the well, and the name, address and telephone

number of the owner of the land where the well will be located if he is not the person responsible for plugging the well; and

(g) A notarized affidavit signed by the person responsible for plugging the well which states that he will be responsible for plugging the well if it is abandoned.

2. Each waiver for an exploratory well will bear a unique number preceded by the letter "W." The notice of intent to drill submitted to the division pursuant to NAC 534.320 and the record of work submitted to the division pursuant to NRS 534.170 must bear this number.

3. An application to appropriate water must be on file with the division or accompany each request for a waiver.

4. A copy of the waiver must be in the possession of the well driller at the drill site.

5.The exploratory well must be:

(a) Plugged by the well driller in the manner prescribed in NAC 534.420 within 3 days after the completion of the aquifer tests for which the well was drilled; or

(b) Completed as a well pursuant to the provisions of this chapter before the drill rig is removed from the drill site.

6. The water from the well may not be used for any purpose other than the purposes set forth in the waiver without the written approval of the state engineer.

[St. Engineer, Drilling Wells Reg. Part 16, eff. 5-19-81]—(NAC A 1-9-90; 12-30-97)

NAC 534.442 Waiver to use water to explore for minerals. (NRS 534.020, 534.110)

1. A request for a waiver to allow a temporary use of water from an existing well to explore for minerals or to drill a well and to use the water from the well to explore for minerals must be submitted to the state engineer in writing and contain:

(a) The amount of water that will be used each day;

(b) A brief description of the manner in which the water will be put to a beneficial use;

(c) The location of the water well by public survey, county assessor's parcel number and plat map;

(d) The name, address and telephone number of the person who will be responsible for plugging the well, and the name, address and telephone number of the owner of the land where the well will be located if he is not the person responsible for plugging the well;

(e) A notarized affidavit signed by the person responsible for plugging the well which states that he will be responsible for plugging the well if it is abandoned;

(f) The name, address and telephone number of a person who will be available to answer questions concerning the well; and

(g) The date the project is scheduled to be completed.

2. A waiver granted for the temporary use of water from a well for the exploration of minerals will bear a unique number preceded by the letters "MM." The notice of intent to drill submitted to the division pursuant to NAC 534.320 and the record of work submitted to the division pursuant to NRS 534.170 must bear this number.

3. A copy of the waiver must be in the possession of the well driller at the drill site.

4. The well must be plugged in the manner prescribed in NAC 534.420 within 3 days after the completion of the project.
5. The water from the well may not be used for any purpose other than the purpose set forth in the waiver without the written approval of the state engineer.

(Added to NAC by St. Engineer, eff. 1-9-90; A 12-30-97)

NAC 534.444 Waiver to use water to explore for oil, gas or geothermal resources. (NRS 534.020, 534.110)

1. A request for a waiver to allow the temporary use of water from an existing well to explore for oil, gas or geothermal resources, or to drill a well and use the water from the well to explore for oil, gas or geothermal resources, must be submitted to the state engineer in writing and contain:
   (a) The location of the proposed water well and the oil, gas or geothermal well by public survey, county assessor's parcel number and plat map;
   (b) The oil, gas or geothermal state or federal permit and lease number, name of the well and American Petroleum Institute number, if assigned;
   (c) The amount of water that will be consumed from the well each day;
   (d) The date the project is scheduled to be completed;
   (e) The name, address and telephone number of the person responsible for plugging the well, and the name, address and telephone number of the owner of the land if he is not the person who is responsible for plugging the well;
   (f) A notarized affidavit signed by the person responsible for plugging the well which states that he will be responsible for plugging the well if it is abandoned; and
   (g) The name, address and telephone number of a person who will be available to answer questions concerning the well.
2. A waiver that allows the temporary use of water from a water well to explore for oil, gas or geothermal resources will bear a unique number preceded by the letters "OG." The notice of intent to drill submitted to the division pursuant to NAC 534.320 and the record of work submitted to the division pursuant to NRS 534.170 must bear this number.
3. A copy of the waiver must be in the possession of the well driller at the drill site.
4. The well must be plugged in the manner prescribed in NAC 534.420 within 3 days after the completion of the project.
5. The water from the well may not be used for any purpose other than the purpose set forth in the waiver without the written approval of the state engineer.

(Added to NAC by St. Engineer, eff. 1-9-90; A 12-30-97)

NAC 534.446 Waiver to use water for construction of highway. (NRS 534.020, 534.110)

1. A request for a waiver to allow the temporary use of water from an existing well for the construction of a highway, or to drill a well and use the water from the well for the construction of a highway, must be submitted to the state engineer in writing and contain:
   (a) The location of the proposed water well by public survey, county assessor's parcel number and plat map;
   (b) The project and contract number, if applicable;
   (c) The total amount of water that will be consumed each day;

(d) The name, address and telephone number of the person responsible for plugging the well, and the name, address and telephone number of the owner of the land where the well will be located if he is not the person responsible for plugging the well;
(e) A notarized affidavit signed by the person responsible for plugging the well which states that he will be responsible for plugging the well if it is abandoned;
(f) The name, address and telephone number of a person who will be available to answer questions concerning the project; and
(g) The date the project is scheduled to be completed.

2. A waiver that allows the temporary use of water from a well for the construction of a highway will bear a unique number preceded by the letter "C." The notice of intent to drill submitted to the division pursuant to NAC 534.320 and the record of work submitted to the division pursuant to NRS 534.170 must bear this number.
3. A copy of the waiver must be in the possession of the well driller at the drill site.
4. The well must be plugged in the manner prescribed in NAC 534.420 within 3 days after the completion of the project.
5. The water from the well may not be used for any purpose other than the purpose set forth in the waiver without the written approval of the state engineer.

(Added to NAC by St. Engineer, eff. 1-9-90; A 12-30-97)

NAC 534.448 Waiver to drill well in shallow ground water system to alleviate certain potential hazards. (NRS 534.020, 534.110)

1. A request for a waiver to drill a well in a shallow ground water system for removing water for the purpose of alleviating potential hazards to persons and property resulting from the rise of ground water caused by secondary recharge must be submitted to the state engineer in writing and contain:
(a) The location of the proposed well by public survey, county assessor's parcel number and plat map;
(b) The project and contract number, if applicable;
(c) The total amount of water that will be consumed each day;
(d) The name, address and telephone number of the person responsible for plugging the well, and the name, address and telephone number of the owner of the land where the well will be located if he is not the person responsible for plugging the well;
(e) A notarized affidavit signed by the person responsible for plugging the well which states that he will be responsible for plugging the well if it is abandoned;
(f) The name, address and telephone number of a person who will be available to answer questions concerning the project; and
(g) The date the project is scheduled to be completed.
2. A waiver to drill a well in a shallow ground water system for removing water for the purpose of alleviating potential hazards to persons and property resulting from the rise of ground water caused by secondary recharge will bear a unique number preceded by the letters "DW." The notice of intent to drill submitted to the division pursuant to NAC 534.320 and the record of work submitted to the division pursuant to NRS 534.170 must bear this number.
3. A copy of the waiver must be in the possession of the well driller at the drill site.

4. The well must be plugged in the manner prescribed in NAC 534.420 within 3 days after the completion of the project.
5. The water from the well may not be used for any purpose other than the purpose set forth in the waiver without the written approval of the state engineer.

(Added to NAC by St. Engineer, eff. 12-30-97)

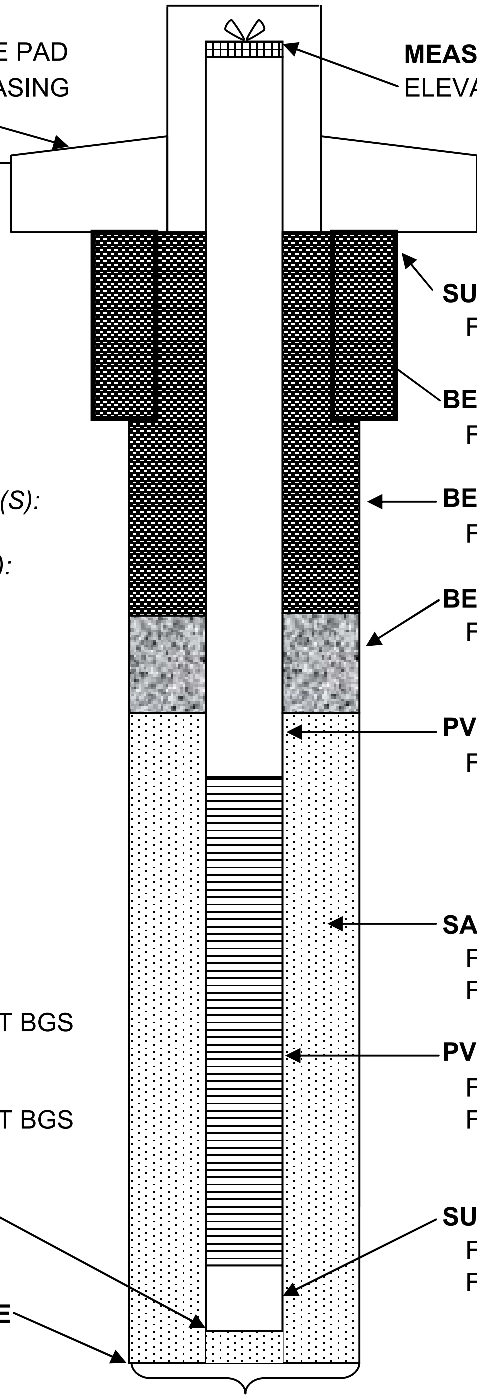
NAC 534.450 Waiver of requirements of chapter. (NRS 534.020, 534.110)

1. Except as otherwise provided in subsection 2, the state engineer may, for good cause shown, waive a requirement of the provisions of this chapter.
2. The state engineer will not waive the requirements set forth in paragraph (c) of subsection 3 of NAC 534.360.
3. A request for a waiver of a requirement of this chapter must be made in writing and include:
   - (a) A brief statement of the reason for requesting the waiver and the section of the regulations to be waived;
   - (b) The location or proposed location of the well by public survey;
   - (c) The name and address of the owner of the well;
   - (d) The street address of the location of the well or, if there is no street address, a description of the location of the proposed well, including, but not limited to, common landmarks and cross-streets near the location of the well;
   - (e) The county assessor's parcel number for the location of the proposed well;
   - (f) A description of the proposed design and a sectional drawing of the proposed well that includes the depths to the aquifers, the locations of the screens and seals and the materials that will be used;
   - (g) A notarized affidavit provided by the division and signed by the owner of the land where the well will be located or his authorized agent which states that the owner of the land will be responsible for plugging the well if it is abandoned;
   - (h) Any available data to categorize the hydraulic heads, water quality and permeability characteristics of the aquifer;
   - (i) A monitoring plan; and
   - (j) Any other information required pursuant to the provisions of this chapter.
4. After reviewing the request, the state engineer will issue a written notice of his decision to the owner of the well.
5. Each waiver will bear a unique number preceded by the letter "R." The notice of intent to drill submitted to the division pursuant to NAC 534.320 and the record of work submitted to the division pursuant to NRS 534.170 must bear this number.
6. The well driller shall ensure that the well complies with the provisions of the waiver and have a copy of the waiver in his possession when he drills the well.
7. The water from the well may not be used for any purpose other than the purpose set forth in the waiver without the written approval of the state engineer.

[St. Engineer, Drilling Wells Reg. Part 15, eff. 5-19-81)—(NAC A 1-9-90; 12-30-97)

TITANIUM METALS CORPORATION FACILITY

MONITOR WELL COMPLETION RECORD



STICK-UP MOUNT CONCRETE PAD WITH 4-INCH PROTECTIVE CASING

MEASURING PT: *TOP OF CASING*
ELEVATION TOC: _____ FT AMSL

GROUND SURFACE
ELEVATION: 0 FT AMSL

WELL DATA

WELL NO:

CLUSTER:

WATER-BEARING ZONE:

DATES

DRILLING DATE(S):

CASING INSTALLATION DATE(S): NA

WELL INSTALLATION DATE(S):

PAD COMPLETION DATE(S):

DRILLING INFORMATION

DRILLING COMPANY:

DRILLERS LICENSE NO:

DRILLING METHOD:

Rota-Sonic ☐
FROM: _____ TO: _____ FT BGS

HSA ☐
FROM: 0 TO: _____ FT BGS

TOTAL DEPTH OF WELL
_____ FT BGS
_____ FT AMSL

TOTAL DEPTH OF BOREHOLE
_____ FT BGS
_____ FT AMSL

SURFACE CASING *(specify)*
FROM: NA TO: _____ FT BGS

BENTONITE GROUT (14.0-IN HOLE)
FROM: NA TO: _____ FT BGS

BENTONITE GROUT (4.25-IN HOLE)
FROM: 0 TO: _____ FT BGS

BENTONITE PELLETS
FROM: _____ TO: _____ FT BGS

PVC RISER CASING (*specify here*)
FROM: +3 TO: _____ FT BGS

SAND PACK 20/40 SAND
FROM: _____ TO: _____ FT BGS
FROM: _____ TO: _____ FT AMSL

PVC SCREEN (2-IN. SCH. 80 PVC 0.010 SLOT)
FROM: _____ TO: _____ FT
FROM: _____ TO: _____ FT AMSL

SUMP LENGTH _____ FT
FROM: _____ TO: _____ FT BGS
FROM: _____ TO: _____ FT AMSL

BOREHOLE DIAMETER _____ INCHES

FT BGS = FEET BELOW GROUND SURFACE
FT AMSL=FEET ABOVE MEAN SEA LEVEL

1.0 INTRODUCTION

All drilling methods impair the ability of an aquifer to transmit water to a drilled hole. This impairment is typically a result of disturbance of soil grains (smearing) or the invasion of drilling fluids or solids into the aquifer during the drilling process. The impact to the hydrologic unit surrounding the borehole must be remediated so that the well hydraulics and samples collected form the monitoring well are representative of the aquifer.

Well development should be conducted as an integral step of monitoring well installation to remove the finer-grained material, typically clay and silt, from the geologic formation near the well screen and filter pack. (Monitoring well installation is discussed in Standard Operating Procedure [SOP] No. 100). The fine-grained particles may interfere with water quality analyses and alter the hydraulic characteristics of the filter pack and the hydraulic unit adjacent to the well screen. Well development improves the hydraulic connection between water in the well and water in the formation. The most common well development methods are surging, overpumping, and bailing.

The health and safety plan for the site should be followed to avoid exposure to chemicals of concern. Water, sediment, and other waste removed from a monitoring well should be disposed of in accordance with applicable federal, state, and local requirements.

1.1 PURPOSE

This SOP establishes the requirements and procedure for monitoring well development. Well development improves the hydraulic characteristics of the filter pack and borehole wall by performing the following functions:

- Reducing the compaction and the intermixing of grain sizes produced during drilling by removing fine material from the pore spaces.
- Removing the filter cake or drilling fluid that coats the borehole as well as much or all of the drilling fluid and natural formation solids that have invaded the formation.
- Creating a graded zone of sediment around the screen, thereby stabilizing the formation so that the well can yield sediment-free water.

1.2 SCOPE

This SOP applies to the development of newly installed monitoring wells. The SOP identifies the most commonly used well development methods; these methods can be used individually or in combination to achieve the most effective well development. Selection of a particular method will depend on site conditions, equipment limitations, and other factors. The method selected and the rationale for selection should be documented in a field logbook or appropriate project reports.

1.3 DEFINITIONS

Aquifer: A geologic formation, group of formations, or part of a formation that is saturated and capable of storing and transmitting water.

Aquitard: A geologic formation, group of formations, or part of a formation through which virtually no water moves.

Bailer: A cylindrical sampling device with valves on either end, used to extract water from a well or borehole.

Bentonite seal: A colloidal (extremely fine particle that will not settle out of solution) clay seal separating the sand pack form the surface seal.

Drilling fluid: A fluid (liquid or gas) that may be used in drilling operations to remove cuttings from the borehole, to clean and cool the drill bit, and to maintain the integrity of the borehole during drilling.

Filter pack: A clean, uniform sand or gravel placed between the borehole wall and the well screen to prevent formation material from entering the screen.

Grout Seal: A fluid mixture of (1) cement and water or (2) cement, bentonite, and water that is placed above the bentonite seal between the casing and the borehole wall to secure the casing in place and keep water from entering the borehole.

Hydraulic conductivity: A measure of the ease with which water moves through a geologic formation. Hydraulic conductivity, K, is typically measured in units of distance per time in the direction of groundwater flow.

Hydrologic units: Geologic strata that can be distinguished on the basis of capacity to yield and transmit fluids. Aquifers and confining units are types of hydrologic units.

Oil air filter: A device used to remove oil from the compressed air discharged form an air compressor.

Oil trap: A device used to remove oil from the compressed air discharged from an air compressor.

Riser: The pipe extending from the well screen to or above the ground surface.

Specific conductance: A measure of the ability of the water to conduct an electric current. Specific conductance is related to the total concentration of ionizable solids in the water and is inversely proportional to electrical resistance.

Static water level: The elevation of the top of a column of water in a monitoring well or piezometer that is not influenced by pumping or conditions related to well installation, hydrologic testing, or nearby pumpage.

Transmissivity: The volume of water transmitted per unit width of an aquifer over the entire thickness of the aquifer flow, under a unit hydraulic gradient.

Well screen: A cylindrical pipe with openings of a uniform width, orientation, and spacing used to keep materials other than water from entering the well and to stabilize the surrounding formation.

Well screen jetting (hydraulic jetting): A jetting method used for development; nozzles and a high pressure pump are used to force water outwardly through the screen, the filter pack, and sometimes into the adjacent geologic unit.

1.4 REFERENCES

American Society for Testing and Materials. 1990. Standard Practice for Design and Installation of Ground Water Monitoring Wells in Aquifers. D5092-90. West Conshohocken, Pennsylvania.

California Department of Toxic Substances Control. 1994. Monitoring Well Design and Construction for Hydrogeologic Characterization. Guidance for Groundwater Investigations. August.

Driscoll, F.G. 1986. Groundwater and Wells (Second Edition). Johnson Division, UOP, Inc. St. Paul, Minnesota.

U.S. Environmental Protection Agence (EPA). 1991. Handbook of Suggested Practices for the Design and Installation of Ground-Water Monitoring Wells. Office of Research and Development, Environmental Monitoring Systems Laboratory. Washington, DC. EPA/600-4-89/034. March.

EPA. 1994. Well Development. Environmental Response Team SOP #2044 (Rev. #0.0,10/03/94).

2.0 WELL DEVELOPMENT PROCEDURES

This section describes common well development methods, factors to be considered in selecting a well development method, procedures for initiating well development, well development duration, and calculations typically made during well development. In addition to this, procedures described in any work plans for well development should be fully consistent with local and state regulations and guidelines.

2.1 WELL DEVELOPMENT METHODS

Well development methods vary with the physical characterization of hydrologic units in which the monitoring well is screened and the drilling method used. The most common methods include mechanical surging, overpumping, air lift pumping, backwashing, and surge bailing. These methods may be effective alone or may need to be combined (for example, overpumping combined with backwashing). Factors such as well design and hydrogeologic conditions will determine which well development method will be most practical and cost-effective. Commonly used well development methods are described in Sections 2.1.1 through 2.1.5.

The use of chemicals for monitoring well development should be avoided as much as possible. Introduction of chemicals may significantly alter groundwater chemistry in and around the well.

2.1.1 MECHANICAL SURGING

The mechanical surging method forces water to flow in and out of the well screen by operating a plunger (or surge block) in the casing, similar to a piston in a cylinder. A typical surge block is shown in Figure 1. The surge block should fit snugly in the well casing to increase the surging action. The surge block is attached to a drill rod or drill stem and is of sufficient weight to cause the block to drop rapidly on the down stroke, forcing water contained in the borehole into the aquifer surrounding the well. In the recovery stroke or upstroke, water is lifted by the surge block, allowing water and fine sediments to flow back into the well from the aquifer. Down strokes and recovery strokes are usually 3 to 5 feet in length.

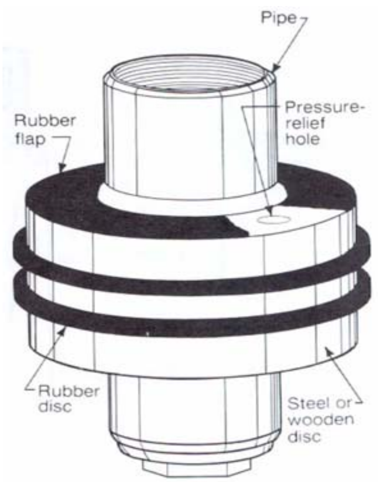


Figure 1 - Surge Block

The surge block should be lowered into the water column above the well screen. The water column will effectively transmit the action of the block to the filter pack and hydrologic unit adjacent to the well screen. Development should begin above the screen and move progressively downward to prevent the surge block form becoming sand locked in the well. The initial surging action should be relatively gentle, allowing any material blocking the screen to break up, go into suspension, and then move into the well. As water begins to move easily both in and out of the screen, the surge block is usually lowered in increments to a level just above the screen. As the block is lowered, the force of the surging movement should be increased. In wells equipped with long screens, it may be more effective to operate the surge block in the screen to concentrate its actions at various levels.

A pump or bailer should be used periodically to remove dislodged sediment that may have accumulated at the bottom of the well during the surging process. The pump or bailer should be moved up and down at the bottom of the well to suspend and collect as much sediment as possible. The accumulation of material developed from a specific screen interval can be measured by sounding the total depth of the well before and after surging. Continue surging until little or no sand accumulates.

2.1.2 OVERPUMPING

Overpumping involves pumping the well at a rate substantially higher than it will be pumped during well purging and groundwater sampling. This method is most effective on coarse-grained formations and is usually conducted in conjunction with mechanical surging or backwashing. Overpumping is commonly implemented using a submersible pump. In cases where the water table is less than 30 feet from the top of the casing, it is possible to overpump the well with a centrifugal pump. The intake pipe is lowered into the water column at a depth sufficient to ensure that the water in the well is not drawn down to the pump intake level. The inflow of water at the well screen is not dependent on the location of the pump intake as long as it remains submerged.

Overpumping will induce a high velocity water flow, resulting in the flow of sand, silt, and clay into the well, opening clogged screen slots and cleaning formation voids and fractures. The movement of these particles at high flow rates should eliminate particle movement at the lower flow rates used during well purging and sampling. The bridging of particles against the screen because of the flow rate and direction created by overpumping may be overcome by using mechanical surging or backwashing in conjunction with this method.

2.1.3 AIR LIFT PUMPING

Air lift pumping uses a two-pipe system consisting of an air injection pipe and a discharge pipe. In this well development method, an air lift pump is operated by cycling the air pressure on and off for short periods of time. This operation provides a surging action that can dislodge fine-grained particles in the vicinity of the well screen. Subsequently applying a steady low pressure removes the fines drawn into the well by the surging action.

The bottom of the air lift should be at least 10 feet above the top of the well screen. Air is injected through an inner pipe at sufficient pressure to bubble out directly into the surrounding discharge pipe. The bubbles formed by the injected air cause the column of water in the discharge pipe to be lifted upward and allow water from the aquifer to flow into the well. This arrangement prevents injected air from entering the well screen. Pumping air through the well screen and into the filter pack and adjacent hydrologic unit should be avoided because it can cause air entertainment, inhibiting future sampling efforts and possibly altering groundwater chemistry.

The air injected into the well should be filtered using an oil/air filter and oil trap to remove any compressor lubricant entrained in the air. Air pressures required for this well development method are relatively low; an air pressure of 14.8 pounds per square inch should move a 30-foot column of water. For small-diameter, shallow wells where the amount of development water is likely to be limited, tanks of inert gas (such as nitrogen) can be used as an alternative to compressed air.

2.1.4 Backwashing

Effective development procedures should cause flow reversals through the screen openings that will agitate the sediment, remove the finer fraction, and then rearrange the remaining formation particles. Backwashing overcomes the bridging that results from overpumping by allowing the water that is pumped to the top of the well to flow back through the submersible pump and out through the well screen. The backflow portion of the backwashing cycle breaks down bridging, and the inflow then moves the fine material toward the screen and into the well.

Some wells respond satisfactorily to backwashing techniques, but the surging effect is not vigorous enough to obtain maximum results in many cases.

A variation of backwashing may be effective in low-permeability formations. After the filter pack is installed on a monitoring well, clean water is circulated down the well casing, out through the well screen and filter pack, and up through the open borehole before the grout or bentonite seal is placed in the annulus. Flow rates should be controlled to prevent floating the filter pack. Because of the low hydraulic conductivity of the formation, negligible amounts of water will infiltrate into the formation. Immediately after this procedure, the bentonite seal should be installed, and the nonformation water should be pumped out of the well and filter pack.

2.1.5 Surge Bailing

Surge bailing can be an effective well development method in relatively clean, permeable formations where water flows freely into the borehole. A bailer made of stainless steel or polyvinyl chloride and slightly smaller than the well casing diameter is allowed to fall freely through the borehole until it strikes the groundwater surface. The contact of the bailer produces a downward force and causes water to flow outward through the well screen, breaking up bridging that has developed around the screen. As the bailer fills and is rapidly withdrawn from the well, the drawdown created causes fine particles to flow through the well screen and into the well. Subsequent bailing can remove these particles from the well. Lowering the bailer to the bottom of the well and using rapid short strokes to agitate and suspend solids that have settled to the well bottom can enhance removal of sand and fine particles. Bailing should continue until the water is free of suspended particles.

2.2 FACTORS TO CONSIDER WHEN SELECTING A WELL DEVELOPMENT METHOD

It is important to check federal, state, and local regulatory requirements for monitoring well development requirements. This SOP may be changed to accommodate applicable regulations, site conditions, or equipment limitations.

The type of geologic material, the design and completion of the well, and the type of drilling method used are all factors to be considered during the development of a monitoring well.

Monitoring well development should usually be started slowly and gently and then performed with increasing vigor as the well is developed. Most well development methods require the application of sufficient energy to disturb the filter pack, thereby freeing fine particles and allowing them to be drawn into the well. The coarser particles then settle around and stabilize the screen.

Development procedures for wells completed in fine sand and silt strata should involve methods that are relatively gentle so that strata material will not be incorporated into the filter pack. Vigorous surging for development can produce mixing of the fine strata and filter pack and produce turbid samples from the formation. In addition, development methods should be carefully selected based upon the potential contaminants present, the quantity of wastewater generated, and requirements for containerization or treatment of wastewater.

For small diameter and small volume wells, a development bailer can be used in place of a submersible pump in the pumping method. Similarly, a bailer can be used in much the same fashion as a surge block in small diameter wells.

Any time an air compressor is used for well development, it should be equipped with an oil air filter or oil trap to minimize the introduction of oil into the screened area. The presence of oil could impact the organic constituent concentrations of the water samples collected from the well.

The presence of light nonaqueous phase liquid (LNAPL) can impact monitoring well development. Water jetting or vacuum-enhanced well development may assist in breaking down the smear zone in the LNAPL. Normal development procedures are conducted in the water-saturated zone and do not affect the LNAPL zone.

2.3 INITIATING WELL DEVELOPMENT

Newly completed monitoring wells should be developed as soon as practical, but no sooner than 24 hours after grouting is completed if rigorous well development methods are used. Development may be initiated shortly after well installation if the development method does not interfere with the grout seal. State and local regulations should be checked for guidance. The following general well development steps can be used with any of the methods described in Section 2.1.

1. Assemble the necessary equipment on a plastic sheet around the well. This may include a water level meter (or oil/water interface probe if LNAPL or dense nonaqueous phase liquid is present); personal protective equipment; pH, conductivity, temperature, and turbidity meters; air monitoring equipment; Well Development Data Sheets (see attached); a watch; and a field logbook.

2. Open the well and take air monitoring reading at the top of the well casing and in the breathing zone. See SOP-54 (Photoionization Detector) for additional guidance.

3. Measure the depth to water and the total depth of the monitoring well.

4. Measure the initial pH, temperature, turbidity, and specific conductance of the groundwater form the first groundwater that comes out of the well. Note the time, initial color, clarity, and odor of the water. Record the results on a Well Development Data Sheet (see attached) or in a field logbook.

5. Develop the well using one or more of the methods described in Section 2.1 until the well is free of sediments and the groundwater turbidity has reached acceptable levels. Record the development method and other pertinent information on a Well Development Data Sheet (see attached) or in a field logbook.

6. Containerize any groundwater produced during well development if groundwater contamination is suspected. The containerized water should be sampled and analyzed to determine an appropriate disposal method.

7. Do not add water to assist in well development unless the water is from a source of known chemical quality and the addition has been approved by the Project Manager. If water is added, five times the amount of water introduced should be removed during development.

8. Continue to develop the well, repeating the water quality measurements for each borehole volume. Development should continue until each water quality parameter is stable to within 10 percent. Development should also continue until all the water added during development (if any) is removed or the water has a turbidity of less than 50 nephelometric turbidity units. This level may only be attainable after allowing the well to settle and testing at low flow sampling rates.

9. At the completion of well development, measure the final pH, temperature, turbidity, and specific conductance of the groundwater. Note the color, clarity, and odor of the water. Record the results on a Well Development Data Sheet (see attached) or in a field logbook. In addition to the final water quality parameters, the following data should be noted on the Well Development Data Sheet; well identification, date(s) of well installation, date(s) and time of well development, static water level before and after development, quantity of water removed and time of removal, type and capacity of pump or bailer used, and well development technique.

All contaminated water produced during development should be containerized in drums or storage vessels properly labeled with the date collected, generating address, well identification, and consultant contact number.

2.4 DURATION OF WELL DEVELOPMENT

Well development should continue until representative water, free of the drilling fluids, cuttings, or other materials introduced during well construction is obtained. When pH, temperature, turbidity, and specific conductance readings stabilize and the water is visually clear of suspended solids, the water is representative of formation water. The minimum duration of well development should vary in accordance with the method used to develop the well. For example, surging and pumping the well may provide a stable, sediment free sample in a matter of minutes, whereas bailing the well may require several hours of continuous effort to obtain a clear sample.

An on-site project geologist should make the final decision as to whether well development is complete. This decision should be documented on a Well Development Data Sheet (see attached) or in a field logbook.

2.5 CALCULATIONS

The minimum number of gallons to be removed must be calculated before the development process begins. At a minimum, three well volumes must be removed during development. Additional water may need to be purged to allow the parameters to stabilize.

Information needed to calculate purge volume:

- Total depth of well (TD)
- Measured static water level (WL)
- Screen length (SL)
- Well casing inner diameter (ID)
- Borehole Diameter (BD)
- Number of gallons of water used during well drilling/construction
- Number of feet of filter pack installed above the screen, if the standing water column (SWC) is longer then the screen length

To calculate one well volume:

- Calculate the standing water column (SWC). TD - WL = SWC.
- Use a well volume chart (Chart 1) to find a multiplier in the volume per linear foot column that coincides with the well's ID.
- SWC times ID multiplier equals gallons of water in one well volume

To calculate one annulus volume (two options):

Option 1 (if the SWC is shorter than the screen length):

- Portion of saturated annulus equals SWC
- Use a volume chart to find a multiplier in the volume per linear foot column that coincides with the well's BD
- BD multiplier minus ID multiplier equals annulus multiplier
- Feet of saturated annulus times annulus multiplier times 30 percent (assumed porosity) equals gallons of water in one annulus volume

Option 2 (if the SWC is longer than the screen length):

- Portion of saturated annulus is equal to the screen length plus the number of feet of sand above the top of the screen
- Use a volume chart (Chart 2) to find a multiplier in the volume per linear foot column that coincides with the well's BD
- BD multiplier minus ID multiplier equals annulus multiplier

- Feet of saturated annulus times annulus multiplier times 30 percent (assumed porosity) equals gallons of water in one annulus volume

To calculate the minimum gallons to be removed:

- Well volume plus annulus volume plus number of gallons lost during well drilling/construction equals one purge volume

Chart 1 – Volume of PVC Casing

Schedule	Diameter (inches)	OD (inches)	ID (inches)	Volume/LF (gallons)
40	1.25	1.660	1.380	0.08
40	2	2.375	2.067	0.17
40	3	3.500	3.068	0.38
40	4	4.500	4.026	0.66
40	6	6.625	6.0625	1.50
40	8	8.625	7.981	2.60
40	12	12.750	11.981	5.82
80	2	2.375	1.939	0.15
80	4	4.500	3.826	0.60
80	5			0.00

Chart 2 – Volume of Open Borehole and Annulus Between Casing and Hole

Hole Diameter	Volume/Linear Feet of Hole		Nominal Casing Diameter	Volume / Linear Feet of Annulus	
(inches)	(gallons)	(cubic feet)	(inches)	(gallons)	(cubic feet)
7.25	2.14	0.29	1.3	2.08	0.28
7.25	2.14	0.29	2.0	1.98	0.26
7.75	2.45	0.33	2.0	2.29	0.31
8.25	2.78	0.37	2.0	2.61	0.35
10.25	4.29	0.57	2.0	4.12	0.55
8.25	2.78	0.37	3.0	2.41	0.32
10.25	4.29	0.57	3.0	3.92	0.52
12.25	6.12	0.82	3.0	5.76	0.77
8.25	2.78	0.37	4.0	2.12	0.28
10.25	4.29	0.57	4.0	3.63	0.49
12.25	6.12	0.82	4.0	5.47	0.73
12.25	6.12	0.82	6.0	4.65	0.62

3.0 POTENTIAL PROBLEMS

The following potential problems can occur during development of monitoring wells:

- In some wells the pH, temperature, and specific conductance may stabilize but the water remains turbid. When this occurs, the well may still contain construction materials (such as drilling mud in the form of a mud cake) and formation soils that have not been washed out of the borehole. Excessive or thick drilling muds cannot be flushed out of a borehole with one or two well volumes of flushing. Continuous flushing over a period of several days may be necessary to complete well development. If the well is completed in a silty zone, it may be necessary to sample with low flow methods or filtering.

- Mechanical surging and well jetting disturb the formation and filter pack more than other well development methods. In formations with high clay and silt contents, surging and jetting can cause the well screen to become clogged with fines. If an excessive amount of fines is produced, sand locking of the surge block may result. Well development with these methods should be initiated gently to minimize disturbance of the filter pack and to prevent damage to the well screen.

- Effective overpumping may involve the discharge of large amounts of groundwater. This method is not recommended when groundwater extracted during well development is contaminated with hazardous constituents. If the hazardous constituents are organic compounds, this problem can be partially overcome by passing the groundwater through an activated carbon filter.

- When a well is developed by mechanical surging or bailing, rapid withdrawal of the surge block or bailer can result in a large external pressure outside of the well. If the withdrawal is too rapid and this pressure is too great, the well casing or screen can collapse.

- A major disadvantage of well jetting is that an external supply of water is needed. The water added during well jetting may alter the hydrochemistry of the aquifer; therefore, the water added in this development procedure should be obtained from a source of known chemistry. In addition, the amount of water added during well development and the amount lost to the formation should be recorded.

- The use of air in well development can chemically alter the groundwater, either directly through chemical reaction or indirectly as a result of impurities introduced through the air stream. In addition, air entrainment within the formation can interfere with the flow of groundwater into the monitoring well. Consequently, air should not be injected in the immediate vicinity of the well screen.

TIMET Groundwater Monitoring Program - Well Development Record

TIMET

Well ID __________ DATE _________
Field Personnel ______________________________

Sampling Organization _____ ***TIMET***
Field observations:(weather, well conditions etc.) ______

Surveyed Measuring Point (MP): *TOC* Elevation: ________
Depth to top ________/______ bottom of screen (below MP)
Pump Intake at ____________ (ft. below MP)
Purging Device - pump type ____________________________
Pump Model ____________ volume (bladder plus tubing) _________

Parameter tolerences (%):		**3%**	**+/-10%**	**na**	**+/- 0.1**	**+/-10%**	
Values:							
CLOCK TIME (24 HR)	STATIC WATER DEPTH (SWL)	TEMP ^{0}C ^{0}F ^{0}K	SPECIFIC COND. (µS/cm)	DO (Mg/L)	ORP (Eh)	pH	TURBIDITY (NTU)	Notes/Comments

Well information

Dedicated pump (Y / N)

Stick-up or flush mount (circle)

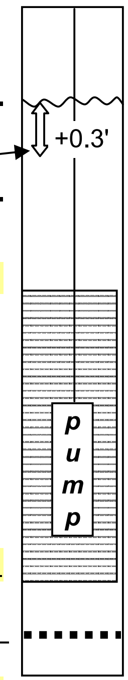
Note: measurements from MP

Static WL ________

drawdown setpoint

____

top of screen ______



Pump intake[2] _______
(depth from MP)

bottom of screen ____

Measured total depth from TOC _____

Blank casing (Y/N)

RECORDED PARAMETERS

INI. DEPTH TO WATER: _________ (static WL with out pump in)
DEPTH TO WATER: _______(W/ PUMP INSTALLED)

CUMULATIVE VOLUME PURGED: ________

NOTES / COMMENTS: ______________________________

Note 1: Shaded cells should be filled in prior to going into the field
Note 2: Pump intake should be set 4 feet +/-0.5 ft from the static water level measured prior to placement of pump

1.0 INTRODUCTION

Estimates of the hydraulic properties of an aquifer are a fundamental component of the site characterization process. Aquifer tests are a means of estimating hydraulic properties, and depending on the data use, the type, duration, and analysis of test is selected.

Generally, longer term pumping tests yield the more reliable estimates of hydraulic properties, particularly in unconfined aquifers where delayed yield may affect observed drawdown. However, at contamination sites, pumped water may or may not constitute investigation derived waste (IDW), which may significantly affect the cost of performing longer duration aquifer tests. Therefore, depending on the data use, shorter duration tests such as single well recovery tests and slug tests, which provided point estimates of transmissivity and hydraulic conductivity, may provide suitable data.

1.1 PURPOSE

Hydraulic properties are used for several purposes, including the following:

- The development of the conceptual site model. Hydraulic properties affect seepage velocities; therefore, their spatial variation may prove important in estimating contaminant migration across a site.

- Estimates of hydraulic conductivity are used to in analytical solutions such as Darcy's Equation for calculation of groundwater seepage velocity.
- Parametric data for input to numerical groundwater flow models and associated solute transport models.
- Hydraulic design for groundwater extraction scenarios.
- Use in wellhead protection studies, determination of the zone of influence and zone of contribution for production wells, and other groundwater basin studies.

1.2 SCOPE

This Standard Operating Procedure (SOP) details four aquifer test methods that are commonly implemented to help characterize an aquifer, and evaluate the performance characteristics of a pumping well: Slug Tests, Step-Tests, Constant Discharge Tests, and Recovery Tests.

Aquifer parameters can be estimated by employing either in situ or ex situ methods. Ex situ methods involve collecting soil samples and testing in a geotechnical lab. In situ methods involve determining the hydraulic characteristics of the aquifer by applying a stress to the aquifer and recording the response to that stress through time. This guideline only considers in situ testing.

1.3 DEFINITIONS

Various physical properties and hydraulic parameters of aquifers and aquitards appear in the equations that describe groundwater flow, and are therefore significant in aquifer testing studies. A working understanding of the hydraulic principles involved in aquifer testing is an essential component of aquifer analysis. A brief definition of terms that are used in this aquifer testing SOP are therefore provided below:

Hydraulic Conductivity: A constant of proportionality that describes fluid flow through a porous media. Hydraulic conductivity (K) is a function of the permeability of the media and of the physical properties of the fluid. Hydraulic conductivity has the units of length/time. In a groundwater setting, the physical properties of the water are considered relatively constant, and therefore hydraulic conductivity can be considered a function of the porous media. For this reason, the terms permeability and hydraulic conductivity are often used interchangeably for groundwater settings. It is important to note that hydraulic conductivity varies over 13 orders of magnitude for earth materials (Freeze and Cherry, 1979).

Transmissivity (T): The product of the hydraulic conductivity (K) and the aquifer thickness (b), and has the dimensions L^2/T. For unconfined aquifers, b is the thickness of the saturated portion of the aquifer.

Total Head: The sum of the elevation head, the pressure head, and the velocity head at any given point in an aquifer.

Potentiometric Surface: An imaginary surface connecting points to which water would rise in cased wells from a given point in an aquifer (Lohman, 1979). It may be above or below the ground surface. The water table is a particular potentiometric surface for unconfined aquifers.

Storativity: The storativity of a confined aquifer is the volume of water released from storage per unit surface area per unit decline in head. For confined aquifers, stored water is released via aquifer compression and expansion of water. In an unconfined (water table) aquifer, the storativity is equivalent to the specific yield. Also known as the storage coefficient. The storativity is dimensionless and typically ranges from 5 × 10-5 to 5 × 10-3 (Kruseman and de Ridder, 1991).

Specific Yield: The specific yield is the volume of water released from an unconfined aquifer from storage per unit surface area of the aquifer per unit decline in the water table. Also known as the unconfined storativity, effective porosity, or drainable pore space. The specific yield is unitless and typically ranges from 0.01 to 0.3 (Kruseman and de Ridder, 1991).

Static Water Level: The non-pumping, stabilized water level in a cased well. Usually recorded in the field as depth to water below a datum such as the top of casing (TOC). This term is usually reported in feet mean sea level.

Specific Capacity: The specific capacity is defined as the discharge rate per unit length of drawdown for a pumping well. Typically expressed in gallons per minute (gpm) per foot of drawdown.

Drawdown: The amount of water level decline in a well and aquifer due to pumping. Usually measured and reported in terms of feet of drawdown relative to static (non-pumping) conditions (s' by convention).

Residual Drawdown: Once a pump is shut off during a pumping test, water levels in the pumping well and observation wells or piezometers will rise. This rise in total head results from the principle of superposition, and is commonly known as residual drawdown (s' by convention). It is expressed as the difference between the static water level and the water level at time t' after the cessation of pumping.

1.4 PERSONNEL QUALIFICATIONS

Due to the technical nature of the testing described in this SOP, the following qualifications are required for personnel designing, operating, and evaluation this test:

- The design of the aquifer testing should be conducted by a senior level geologist/hydrogeologist with experience relevant to the aquifer being studied

- The operation of the test can be conducted by an experienced geologist with assistance from junior-level personnel under their supervision
- The data evaluation should be conducted by the senior-level geologist/hydrogeologist that constructed the design, if available; otherwise, another senior level geologist/hydrogeologist with experience with the aquifer being studied.

1.5 REFERENCES

Bouwer, H. and Rice, R.C., 1976. A slug test method for determining the hydraulic conductivity of unconfined aquifers with completely or partially penetrating wells, Water Resources Research, vol. 12, no. 3, pp. 423-428.

Cooper, H.H., and Jacob, C.E., 1946. A generalized graphical method for evaluating formation constants and summarizing well field history, Am. Geophys. Union Trans. vol 27, pp. 526-534.

Cooper, H.H., Bredehoeft, J.D., and Papadopulos, S.S., 1967. Response of a finite-diameter well to an instantaneous charge of water, Water Resources Research, vol. 3, no. 1, pp. 263- 269.

Dansby, D.A., and Price, C.A., 1987. Graphical Well Analysis Package "GWAP" v.2.0, Groundwater Graphics, 5209 Windmill Street, Oceanside, CA 92056. ph. (619) 940- 9473.

Driscoll, F.G., 1986. Groundwater and Wells. 2nd Ed., Johnson Division of Wells, St. Paul, Minnesota. Freeze, R.A., and J.A. Cherry, 1979. Groundwater, Prentice-Hall, Inc., Englewood Cliffs, N.J.

Freeze, R.A. and Cherry, J.A., 1979, Groundwater: Englewood Cliffs, N.J., Prentice Hall, 604 p.

HydroSolve, Inc., 2003. Aquifer Test Solver "AQTESOLV" v.3.5, Reston, Virginia.

Hantush, M.S. and C.E. Jacob, 1955. Non-steady radial flow in an infinite leaky aquifer, Am. Geophys. Union Trans., vol. 36, pp. 95-100.

Hantush, M.S., 1960. Modification of the theory of leaky aquifers, Jour. of Geophys. Res., vol. 65, no. 11, pp. 3713-3725.

Kruseman, G.P., and N.A. de Ridder, 1991. Analysis and Evaluation of Pumping Test Data, 2nd Ed., Nat'l Institute for Land Reclamation and Improvement/ILRI, Wageningen, The Netherlands, 377p. Available through the NWWA Bookstore.

Lohman, S.W., 1979. Ground-Water Hydraulics, USGS Prof. Paper 708. Available through the USGS "Books and Open-File Reports Section, Federal Center, Box 25425 Denver, Colorado 80225.

Moench, A.F., 1996. Flow to a Well in a Water-Table Aquifer: An Improved Laplace Transform Solution. Ground Water, vol. 34. No. 4, pp. 593-596

Neuman, S.P., 1975. Analysis of pumping test data from anistropic unconfined aquifers considering delayed yield, Water Resources Research, Vol 11, No. 2, pp. 329-342.

Neuman, S.P., and P.A. Witherspoon, 1972. Field Determination of Hydraulic Properties of Leaky Multiple-Aquifer Systems. Water Resources Res. Vol. 8, No. 5, October 1972, pp. 1284 - 1298.

Schafer, D.C., 1978. Casing storage can affect pumping test data. The Johnson Drillers Journal, January-February, 1978.

Thiem, G., 1906. Hydrologische Methoden. Gebhardt, Leipzig, 56p.

Theis, C.V., 1935. The relation between the lowering of the piezometric surface and the rate and duration of discharge of a well using groundwater storage, Am. Geophys. Union Trans., Vol. 16, pp. 519-524.

Waterloo Hydrogeologic, Inc., 2002. AquiferTest Pro v.3.5, Waterloo, Ontario, Canada.

2.0 AQUIFER TESTING METHODS

Slug tests, step-tests, pumping tests, and recovery tests have different applications and limitations. In general, step-drawdown tests, constant rate pumping tests, and recovery tests that incorporate observation wells require pumping groundwater from an aquifer, and are therefore most feasible for relatively high transmissivity zones, such as alluvial sand and gravel aquifers, or extensively fractured aquifers. In these types of aquifers, a long-term pumping test is the most accurate means of evaluating aquifer properties, and for evaluating other aquifer properties such as boundary conditions, heterogeneity, and anisotropy. With zones having sufficient transmissivity, pumping rates can be achieved that will create significant drawdown in observation wells. Conversely, pumping tests are less effective, or even infeasible, in units having low transmissivity (e.g., clays and silts) because sufficient extraction rates cannot be achieved. For low transmissive zones, the preferred aquifer test method is a slug test, described below.

2.1 SLUG TESTING

Slug testing involves introducing or removing a "slug" of known volume into a well and recording the water level changes that result from either the instantaneous insertion or instantaneous withdrawal of the slug. The rate of recovery observed in the well is a function of the hydraulic conductivity of the aquifer and of the well hydraulic properties itself.

Slug tests stress only a small portion of the aquifer adjacent to the well, and therefore, slug tests are incapable of evaluating hydrogeologic boundary conditions, hydraulic anisotropy, storage coefficients, and pumping characteristics of the well. However, slug tests commonly provide a cost-effective means of gathering "point" values for hydraulic conductivity across a large area.

If a slug is rapidly inserted into the water column in a well, it will instantaneously raise the water column in the well. The amount of head change is defined as the instantaneous head (Ho). The water column will then "fall" to the static water level at a rate that is controlled by the hydraulic characteristics of the water-bearing formation and of the well itself. The slug insertion method is also known as a "falling head" test for this reason.

A second approach, the slug withdrawal method, requires submersing the slug in the water column within a well and allowing the water level to stabilize to static conditions. The slug is then rapidly withdrawn from the well. After the slug is withdrawn from the well, the instantaneous water level will be at a level that is lower than the static water level. The rate at which the water levels recover to static water levels is a function of the aquifer properties and of the well itself. This method is also known as a "rising head" test.

Both methods can be used in series during a slug testing program. The slug insertion method may be followed by the slug withdrawal with relative ease. However, if a slug insertion method is chosen for unconfined aquifers, groundwater will be displaced above the water table and into the unsaturated sand filter pack of the well and the formation itself. It is noted that the hydraulic conductivity of the soils overlying the water-bearing zone may differ from those of the aquifer. Additionally, hydraulic conductivity of unsaturated soils varies as a function of moisture content. For these reasons, only the slug withdrawal method should be used in unconfined or semiconfined aquifers. If the static water level is within the screened interval of the well that is being tested, a slug withdrawal method should be chosen for aquifer analysis.

Several different types of slugs may be used for the test, including:

- Solid (blank) polyvinyl chloride (PVC) pipe filled with sand and fitted with an eye bolt at one end to affix a bailing line
- Stainless steel or Teflon™ bailers
- A slug of water of known volume

Introduction of a slug of water (usually distilled, organic-free water) may not be feasible due to regulatory restrictions. In addition, it is generally considered infeasible to "instantaneously" withdraw a slug of water using a pump. The withdrawal of a slug of water is limited to the use of bailers. The most common slug test involves the use of solid pipes (either slug insertion or withdrawal methods) or use of bailers (slug withdrawal only). An additional slug testing method involves applying a pressure or vacuum to the well head and measuring changes in water levels that result following the removal of the pressure. This method requires specialized well fittings, generators, and compressors. Details of the method are provided in Kruseman and de Ridder (1991) (Oscillation Method, p.238), and are not included in this SOP.

The remainder of this SOP focuses on slug tests conducted using a solid slug, although the general methods for slug tests analyses do not vary significantly if other types of slugs are used for the test.

A large slug will stress the aquifer to a greater degree than a small slug, and therefore the size of the slug should be maximized based on field conditions. Three-foot Teflon bailers or sections of solid pipe can be threaded together to optimize slug volume. The size of the slug is limited only by the standing water column in the well and physical limitations in one's ability to instantaneously insert or withdraw the slug.

2.1.1 Solid Slug Required Equipment

Slug. Solid pipe may be used for slug insertion or withdrawal. Bailers may be used for slug withdrawal only. The slug volume should be maximized based on field conditions. Different length slugs capable of threading together should be brought to the field to provide flexibility to the program. A typical slug used for a 2-inch diameter monitoring well may be 1.5 inches in diameter and 6 to 10 feet in length. The volume of the slug used for each test must be recorded in the field notes.

Bailing Line. Used for rapidly lowering and raising the slug into the water column. Deep wells may require the use of the winch on a smeal rig.

Water Level Indicator. Instrument used for easuring static water levels. A conductivity-based water level indicator capable of measuring to 0.01-foot accuracy is required.

Pressure Transducer. Device installed in the well below the slug that is capable of continuously providing very accurate water level measurements. The transducer will be connected to a continuous data logger (described below). Transducers are available in different pressure (and accuracy) ranges. Higher pressure range transducers are less accurate than lower pressure range transducers. The transducers should never be lowered into a water column below the operating pressure range of the transducer. As a rule, a multiplier of 2.3 can be used to estimate the maximum total amount of water above a transducer, i.e., a 10-psi transducer can have 23 feet of water above, a 50-psi transducer can have 106 feet of water above, etc. For example, if a 10-psi transducer is installed at the bottom of the well with 100 feet of water above it, it will no longer function properly, and must be returned to the manufacturer for recalibration. The transducer only needs to record the change in water levels imparted by the slug, and therefore should be installed immediately below the total depth of the slug. A 10-psi transducer is capable of measuring up to 23 feet of change in water levels to 0.01-foot accuracy, and is the recommended transducer for slug tests. Transducers should never be lowered to the bottom of the well because they operate improperly if lowered into sediment. The target depth of the transducer should be identified prior to lowering into the well and the transducer cable marked with duct tape to ensure that the transducer is not lowered too deep.

Data Logger. This device is a small field computer capable of recording a wide range of physical measurements such as pressures, temperatures, electrical conductivities, and flow. For aquifer analysis, we are generally interested in recording pressure (feet of water in the well). The data logger converts the pressure value sent by the transducer into feet of water above the transducer, and records the values in its memory. The data can then be downloaded from the logger to personal computer. It is noted that each transducer has specific parameters that must be input to the data logger to make the appropriate conversions from pressure units to feet. The person operating the data logger must be properly trained and have sufficient experience with the instruments to eliminate compromising or even loss of slug test data. The owner's manual must be consulted before using. Common models are the Hermit 3000 (multi-channel, very user friendly), Hermit 2000, and Hermit 1000 (2-channel, less friendly), and most recently the mini-TROLL, which is a combination logger and transducer.

Duct Tape. Used to affix the transducer cable to an immobile object such as the top of the well casing.

Health and Safety Equipment. Based on the requirements of the facility health and safety plan.

Decontamination of all down-hole equipment must follow site-specific decontamination procedures.

2.1.2 Personnel Requirements

Slug testing generally requires a two-person team. One person prepares and rapidly inserts or withdraws the slug and collects water level measurements manually. The second person operates the field instruments and double checks the quality of the data. Background conditions that may influence water levels during the test, such as weather conditions, nearby soil vapor extraction systems, or groundwater extraction systems, should be evaluated. Monitoring of water levels in a background monitoring well that is screened in a representative water-bearing unit should be performed.

2.1.3 Slug Insertion Test Methods

1. Remove the well head expansion cap and allow the well to equilibrate to atmospheric conditions.

2. Record the static water level using a conductivity-based water level indicator. Sound the well. Note potential sediment at bottom.

3. Determine the appropriate depth of 10-psi transducer. This will generally be between 10 and 20 feet below the static water level, or above potential sediment at bottom of shallow wells. Affix duct tape to transducer cable to indicate the target depth below TOC.

4. Lower a 10-psi transducer to the target depth. The transducer and transducer cable must hang plumb in the well to minimize entanglement with the slug. Duct tape the transducer cable to an immovable object such as the TOC, Christy box, or stovepipe. Allow the well to equilibrate to static water levels.

5. Connect the pressure transducer to a continuous data recorder. Input the required transducer's parameters and other test parameters in the data logger (consult manual). The data logger will typically ask whether you wish to record water levels below the TOC or surface. Surface refers to a static water level datum. This means that when the instrument is "referenced", it is "zeroed" to the static water level, and will therefore measure changes relative to static water level. Water levels above static water levels will be recorded as positive, and water levels below static will be recorded as negative values. The slug test requires only measuring the change in head associated with slug insertion or withdrawal. The "surface mode" is therefore the desired data logger "mode" for slug testing. TOC refers to measuring the absolute value (i.e., total head) of the water level relative to the TOC datum. This unnecessary step may introduce error in the field, and is therefore not recommended for slug testing. An accurate record of all input parameters and field observations must be included in a field aquifer test log.

6. "Zero" the pressure transducer/data logger to static water levels. Confirm static levels with a water level indicator. At this point, you are nearly ready to begin the test. The data logger should be set to begin the test in the "immediate" mode (i.e., no time delay). The data logger should be set to record water levels as frequently as possible within the first couple of minutes (the "log" mode is recommended).

7. Affix a bailing line to the slug. To accurately complete the test, the slug will require complete submersion in the well. Record the volume of the slug in the field log. Determine the total depth required to submerse the slug. A piece of duct tape may be used to identify the desired length. One person should handle the slug, and one person should handle the data logger. The slug should be lowered to a "ready" position immediately above the static water level. The slug must not be tangled with the transducer cable.

8. This is the critical step. On a predetermined count, one person must rapidly (but gently) lower the slug to total submersion while the second person triggers the data logger to begin recording water levels. The slug must remain motionless once it has been lowered into the well. The bailing line for the slug must be tied to an immovable object (e.g., truck tailgate) once the slug is submerged. It is recommended that the data logger be allowed to complete its logarithmic data recording cycle (approximately 2-3 minutes)

prior to confirming water levels with a water level indicator. Wells screened within low to moderately transmissive aquifers may require from 30 seconds to several minutes or even hours to recover to static water levels. If the well recovers within a few seconds, it is likely that the well is screened within a moderate to high transmissivity zone, and therefore the slug test method is likely not an appropriate test method for determination of aquifer properties.

9. The slug injection test is completed when the water level recovers to 90 to 100 percent of static water levels. In many instances, the final few tenths of a foot of recovery may require a significant amount of time (hours). The field team should use their best judgment regarding when to terminate the test. For nearly all methods of data analysis, the last data points are as significant as the initial data points, and the validity of the tests should not be compromised due to impatience of field team members. In many cases, the team can be setting up the next test on a different well while the previous well completes its recovery.

10. Once the well has equilibrated to 90 to 100 percent (or nearly 100 percent) of static water level, the test can be terminated by stopping the data logger. However, at this time, it would be advantageous to initiate a slug withdrawal test (see item No. 4 below). This may be accomplished by either "stopping" the insertion test, or "stepping" the test by using the "Step" function of the data logger. The original input parameters remain unchanged if you choose to use the "Step" function or stop and start function. Both methods involve restarting the "log cycle" for the data logger (highly desirable for the early time data). An accurate record of test numbers and step numbers must be included in the field logs.

2.1.4 Slug Withdrawal Test Methods

1. Remove the well head expansion cap and allow the well to equilibrate to atmospheric conditions.

2. Record the static water level using a conductivity-based water level indicator. Sound the well. Note potential sediment at bottom.

3. Determine the appropriate depth of a 10-psi transducer. This will generally be between 10 and 20 feet below the static water level, or above potential sediment at bottom of shallow wells. Affix duct tape to transducer cable to indicate the target depth below TOC.

4. Lower a 10-psi transducer to the target depth. The transducer and transducer cable must hang plumb in the well to minimize entanglement with the slug. Duct tape the transducer cable to an immovable object such as the TOC, Christy box, or stovepipe. Allow the well to equilibrate to static water levels.

5. Connect the pressure transducer to a continuous data recorder. Input the required transducers parameters and other test parameters in the data logger. The data logger will typically ask whether you wish to record water levels below the TOC or surface. Surface refers to a static water level datum. What this means is when the instrument is "referenced", it is "zeroed" to the static water level, and will therefore measure changes relative to static water level. Water levels above static water levels will be recorded as

positive, and water levels below static will be recorded as negative values. The slug test requires only measuring the change in head associated with slug insertion or withdrawal. The "surface mode" is therefore the desired data logger "mode" for slug testing. TOC refers to measuring the absolute value (i.e., total head) of the water level relative to the TOC datum. This unnecessary step may introduce error in the field, and is therefore not recommended for slug testing. An accurate record of all input parameters and field observations must be included in a field log.

6. Lower the slug into the water column so the slug is fully submerged. For this test, tie the slug bailing line to an immovable object and allow slug to remain motionless in the well. Ensure that the slug is not entangled with the transducer or transducer cable.

7. Allow the well to equilibrate to the static water level. The well will recover most quickly if a bailer is used for the slug. A solid pipe slug will require a longer recovery period. Verify that the well has equilibrated to static water level with a water level indicator.

8. This is the critical step. On a predetermined count, one person must rapidly (but gently) retrieve the slug from the well while the second person simultaneously triggers the data logger to begin recording water levels. Remove the slug from the well while making sure not to disturb the transducer cable. As stated above, it is recommended to allow the data logger to complete its logarithmic data recording cycle (approximately 2-3 minutes) prior to confirming water levels with a water level indicator. Wells screened within low to moderately transmissive aquifers may require from 30 seconds to several minutes or hours to recover to static water levels. If the well recovers within a few seconds, it is likely that the well is screened within a moderate to high transmissivity zone, and therefore the slug test method is likely not an appropriate test method for determination of aquifer properties. It is recommended that two slug tests be conducted for each well for data verification purposes.

2.2 OVERVIEW OF PUMPING TESTS

This section provides details on the elements of pumping tests.

2.2.1 Pumping Tests

Several different types of pumping tests can be conducted to determine aquifer properties, although the fundamental principles of all tests are similar. The principle of a pumping test involves applying a stress to an aquifer by extracting groundwater from a pumping well and measuring the aquifer response to that stress by monitoring drawdown as a function of time in the pumping well and/or observation wells or piezometers at known distances from the well. These measurements are then incorporated into an appropriate well-flow equation to calculate the hydraulic characteristics of the aquifer and pumping well. Numerous different types of pumping tests and well-flow equations exist that may be implemented for nearly all hydrogeologic settings. Each method has a different set of limitations and assumptions. For unusual tests and hydrogeologic settings, see Kruseman and de Ridder (1991). Different assumptions and limitations exist for confined, semiconfined (leaky), and unconfined (water-table) aquifers. In general, the following assumptions apply to most well-flow equations and hydrogeologic settings:

- The aquifer is of infinite areal extent.

- The aquifer is of uniform thickness and infinite in areal extent.

- Prior to pumping, the potentiometric surface is horizontal (or nearly so) over the area that will be influenced by the pumping test.

- The aquifer is pumped at a constant discharge rate, or for variable discharge rate tests, the rate is known.

- The pumping well fully penetrates the entire thickness of the aquifer and thus receives water by horizontal flow.

Groundwater and Wells (Driscoll, 1986) provides practical guidelines on how to set up and interpret data from aquifer tests.

2.2.2 Pumping Test Method Selection

The overall approach, including capabilities, limitations and assumptions, for three types of pumping tests—Step Tests (variable discharge tests), Constant Discharge Pumping Tests, and Recovery Tests—is detailed in this section.

Step Tests: Involves pumping from a single well at a relatively low rate until drawdown has stabilized. The pumping rate is then increased to a higher discharge rate until drawdown again stabilizes. This procedure is continued for at least three steps. Each step is typically 20 to 40 percent greater than the previous step, with a duration of typically 30 minutes to 120 minutes (Kruseman and de Ridder, 1991; Driscoll, 1986).

In general, step-tests are relatively short duration tests that are capable of providing general well performance characteristics and aquifer transmissivity and storativity near the pumping well. A step-test provides specific capacity data, and should always be conducted prior to a long-term pumping test if no previous pumping data for the well exist. Step-tests are generally considered less effective for determining hydraulic anisotropy, leakage between layers, boundary conditions and recharge areas than long-term pumping tests.

Constant Discharge Pumping Test's: Involves pumping from a well at a continuous, known, constant discharge rate over an extended period of time. This type of test typically involves monitoring drawdown in several observation wells or piezometers, although the test may also be performed as a single-well test. Long-term, constant discharge pumping tests are the most accurate means of evaluating aquifer hydraulic properties. If properly designed and conducted, these types of aquifer tests are capable of evaluating transmissivity, storativity, aquifer anisotropy, leakage from overlying or underlying layers, boundary effects, recharge areas, etc. Additionally, well performance characteristics such as well capacity, well yield, and well efficiency may be determined using a constant discharge pumping test.

Recovery Tests: Constant discharge tests and step tests should generally be followed by a recovery test. A recovery test measures the residual drawdown (s') following the pumping test. The recovery test provides the data required to calculate the transmissivity of the aquifer, thus providing an independent check on the results of the pumping test while costing very little in terms of the total cost of the pumping test (Freeze and Cherry, 1979; and Kruseman and de Ridder, 1991). A recovery test is invaluable if the pumping test is performed without the use of piezometers or observation wells to evaluate potential borehole storage effects of the pumping well. Additionally, residual drawdowns are more reliable than drawdowns measured during pumping due to difficulties in the field of maintaining absolutely constant discharge from a pumping well (i.e., all pumps have a level of discharge variability). It should be noted that recovery tests may be difficult to evaluate if non-ideal conditions exist in the aquifer-such as leaky or boundary conditions.

2.2.3 Equipment Requirements

Electric Submersible Pump. Must be capable of pumping for extended periods at a constant discharge rate. Discharge pipe or hose should be fitted with a valve to provide the ability to adjust flow. The accuracy of the flow meter along with the operational range must be verified and recorded. Adjusting the discharge rate by adjusting the speed of the pump is less desirable than use of a valve. An exception is the variable-speed 2-inch-OD Grundfos submersible pumps, which are designed for adjustable speed (flow) settings. A shroud is recommended if a 2-inch pump is used in a 4-inch or greater diameter well to ensure long-term cooling of the pump motor. The pump will require a reliable power source.

Flow Gauge. An in-line "turbine type" flow meter is recommended for most moderate to high flow-rate applications. Other means of gauging flow are use of calibrated orifice weirs or orifice bucket (Driscoll 1986; Kruseman and de Ridder, 1991). For low flow applications, a container and stopwatch method may be suitable. The container method requires measuring the time it takes to fill a container of known volume such as large bucket or 55-gallon drum. The flow gauging method should be accurate to +/- 5%.

Water Level Indicator. To be used for measuring water levels. A conductivity-based water level indicator capable of measuring to 0.01 foot accuracy is required for all hazardous waste field investigations. Manual water level data should always be invoked as a back-up to electronic water levels recorded using pressure transducers and data loggers. Water level data should be recorded on an aquifer test data sheet for the test designed.

Pressure Transducer. This device should ideally be installed in the well above the pumping level. This device is capable of continuously providing very accurate water level measurements. A transducer that is vented to the atmosphere should be used such that it monitors water level head and not changes in barometric pressure. The transducer will be connected to a continuous data logger (described below). Transducers are available in different pressure (and accuracy) ranges. Higher pressure range transducers are less accurate than lower pressure range transducers. The transducers should never be lowered into a water column below the operating pressure range of the transducer. For example, if a 10-psi transducer is installed at the bottom of the well with 100 feet of water above it, it will no longer function properly. As a rule, a multiplier of 2.3 can be used to estimate the maximum total amount of water above a transducer, (e.g., a 10-psi transducer can have 23 feet of water above it, a 50-psi transducer can have 106 feet of water above). Please note, the transducer only needs to record the drawdown resulting from pumping. A 10-psi transducer is capable of measuring up to 23 feet of change in water levels to 0.01 foot accuracy, and is therefore the recommended transducer for all observation wells used in a pumping test network. Transducers will operate improperly if lowered into sediment, and therefore the transducer should never be lowered to the bottom of the well. The target depth of the transducer should be identified prior to lowering into the well. The transducer cable should be marked with duct tape to demark the target depth. The most accurate (lowest psi rating) transducer should be installed in the well or piezometer with the least anticipated drawdown, i.e., NOT the pumping well. The least accurate transducer (greatest psi rating) should be installed in the pumping well, as it will always show the greatest drawdown.

Data Logger. This device is a small field computer capable of recording a wide range of physical measurements such as pressures, temperatures, electrical conductivities, and flow. The data logger converts the pressure value sent by the transducer into feet of water above the transducer and records the values in its memory. The data can then be downloaded from the logger to a personal computer. It is noted that each transducer has specific parameters that must be input to the data logger to make the appropriate conversions from pressure units to feet. It is extremely important that the person operating the data logger is properly trained and has sufficient experience with the instruments to eliminate compromise or loss of pumping test data. Common models are the Hermit 3000, Hermit 2000 (multi-channel, very user friendly), Hermit 1000 (2-channel, less friendly) and their latest model the mini-troll.

Watch. All project team members must have an accurate wrist watch or stop watch. All watches must be synchronized with the time in the data logger prior to starting any pumping test.

Duct Tape. Used to affix the transducer cable to an immobile object such as the top of the well casing.

Health and Safety Equipment. Based on the requirements of the facility health and safety plan.

Decontamination procedures should follow the site-specific requirements.

2.2.4 Personnel Requirements

Most pumping tests will initially require a minimum of three people. More staff is generally required for long-term constant rate tests than for step tests and recovery tests, which generally can be completed with two field team members. One person should be responsible for monitoring the flow gauge and adjusting the discharge rate of the pump, and for ensuring that the data logger is triggered and operating. Other team members should be responsible for taking manual (back-up) water level measurements with a conductivity-based water level indicator. If the observation wells are located at great distances from one another, or if rapid drawdown is anticipated, it may be advantageous to have several field team members on site to measure and record water levels, particularly during the earlier stages of the test when the most rapid change in water levels is anticipated. As water levels reach a pseudo-steady state, fewer team members will be required.

2.3 STEP-TESTS

This section provides details of the design and field methodology for completion of a step-drawdown test.

2.3.1 Design of the Step Test

The following design components must be evaluated prior to completion of the step-test:

- Choice of pumping well. The well must be fully developed and capable of sustained prolonged pumping. Ideally, the well chosen will be located in the geographic center of the area of interest.

- Size of pump. Should be based on the estimated specific capacity, desired total drawdowns, and head requirements. If no previous pumping data are available, development logs or other field observation data should be assessed to aid in sizing the pump.

- Duration of each step. Ideally, a step-test will consist of at least three steps of progressively increasing discharge rate, followed by one step for recovery. Each step generally should range from 30 minutes to 2 hours. A step test typically requires one 10-hour field day to complete (assumes no mobilization time).

- Initial Discharge Rate. The first step discharge rate should produce approximately 25 percent of the maximum anticipated drawdown estimated from the well specific capacity. If a production well is to be used for the step-test, the initial rate should be approximately 25 percent of the pump capacity. The second step should be approximately 50 percent of the anticipated drawdown and so on.

2.3.2 Step-Testing Methods

1. Remove the well head expansion cap and allow well to equilibrate to atmospheric conditions.
2. Record the static water level using a conductivity-based water level indicator. Sound the well. Note potential sediment at bottom.

3. Determine the appropriate depth of the transducer. Generally, a 10-psi transducer (capable of measuring 23 feet of head change) or 50-psi transducer (capable of measuring 106 feet of head change) are well suited for step-testing. The transducer should be targeted for a level 3 to 5 feet above the pumping level whenever possible to minimize interference with the pump. Affix duct tape to transducer cable to indicate the target depth below TOC.

4. The pump should be set in the well at the desired pumping level. This is usually the screened interval for shallow wells (<100 feet total depth). For deeper wells, the pumping depth only needs to be greater than the anticipated drawdown. For high volume tests, it may be cost effective to hire a pumping subcontractor to operate the pumps, discharge lines, etc. Contaminated groundwater discharged from the well may require storage in Baker tanks or treatment prior to disposal. All disposal options and permitting must be in-place prior to conducting the test. A water disposal option should be chosen that does not impinge on the groundwater flow system during the test via infiltration recharge, etc.

5. Lower the transducer to the target depth. The transducer and transducer cable must hang plumb in the well to minimize entanglement with the pump discharge pipe/hose. Duct tape the transducer cable to an immovable object such as the TOC, Christy box, or stovepipe. Allow the well to equilibrate to static water levels.

6. Connect the pressure transducer to a continuous data recorder. Input the required transducer's parameters and other test parameters in the data logger. The data logger will typically prompt the user to record water levels below the TOC or surface. Surface refers to a static water level datum. The instrument is therefore "referenced" or "zeroed" to the static water level, and will therefore measure changes relative to static water level (the desired mode for steptesting). Water levels below static water level will be recorded as negative values. The step-test requires only measuring drawdown relative to static (and residual drawdown during recovery, if desired). TOC refers to measuring the absolute value (i.e., total head) of the water level relative to the TOC datum. This unnecessary step may introduce error in the field, and is not recommended for step-tests. An accurate record of all input parameters and field observations must be included in a field log.

7. "Zero" the pressure transducer/data logger to static water levels. Confirm static levels with a water level indicator. At this point, you are ready to begin the test. The data logger should be set to begin the test in the "immediate" mode (i.e., no time delay). The data logger should be set to record water levels as frequently as possible during the first couple of minutes of the test (i.e., using the "log" mode).

8. STEP #1. This is the critical step. On a predetermined count, one person must simultaneously trigger the data logger and the pump. The pump operator must quickly stabilize the discharge rate to the desired pumping rate. At the same time, another team member should begin recording water levels as rapidly as possible in the pumping well (every 15 to 30 seconds for the first 5 minutes). It usually helps to have the data table constructed with water level time intervals predetermined. The water level measuring interval may be lengthened to every minute or every five minutes as the test progresses. Field observations suggest that 70-80 percent of the total drawdown for each step will occur within the first 15 to 20 minutes following commencement of pumping. The data recorded by the transducers and data logger can be viewed following completion of the logarithmic data recording cycle (approximately 2-3 minutes). Water levels recorded by the transducer/data logger system should be similar to the manually recorded water levels. It is always beneficial to plot the time and drawdown data in the field to ensure that the pumping rate and the drawdowns are adequate. Allow the test to run until the water level in the pumping well stabilizes to a steady state (or nearly so). This typically requires 30-120 minutes. Field plotting of data is helpful in determining when pseudo-steady state drawdown is achieved.

9. STEP #2. This is also a critical step. On a predetermined count, one person must step-up the pumping discharge rate to the desired level (usually by opening a control valve located upstream of the flow gauge), and a second person should restart the "logarithmic data recording cycle" on the data logger. This is easily done using a Hermit 2000 by using the "STEP" function. It is highly desirable to have a third field team member manually record water levels at each "Step."

10. STEP #3 and STEP #4. Critical Steps. Repeat item 9 above. Make sure to not draw the water level down to the pumping level. It is more desirable to abbreviate the duration of any step and get accurate recovery data (see item 11, below) than to draw the water level down to the pumping level.

11. STEP #5. Critical step. On a predetermined count, simultaneously turn off the pump, "Step" the data logger, and manually record recovery (residual drawdown) data. Continue recording the recovery data until the water level returns to static water levels (or nearly so). The test is completed.

12. This is a very important step. Carefully download the data in the logger. Obtain a hard copy and retain a master electronic copy in the records.

2.4 CONSTANT RATE PUMPING TESTS

Provided below is a detailing of the design and field methodology for the completion of a constant rate pumping test.

2.4.1 Design Considerations for Constant Rate Pumping Tests

Choice of pumping well. The well should be designed as a pumping well, although many monitoring wells have been "converted" to pumping wells for use in a pumping test. In either case, the well must be fully developed and capable of sustained prolonged pumping. Nearby observation wells or piezometers are required for distance-drawdown calculations. If an existing pumping well is used in the test, the pumping history of the well should be known.

Choice of observation wells. Ideally, water levels will be monitored in as many nearby observation wells as feasible. Wells screened at different depth intervals should also be monitored to evaluate hydraulic communication across aquitards. It may be advantageous to equip observation wells that are located near the pumping well with continuous data recording instruments, and manually record water levels for wells located at greater distances. Prior to conducting the pumping test, estimated zones of influence may be completed using well-flow equations to determine which wells will likely show a drawdown response. It is beneficial to use observation wells located upgradient, downgradient, and across gradient from the pumping well to evaluate hydraulic anisotropy.

Size of pump. Should be based on the drawdown requirements and estimated specific capacity determined from a step-drawdown test or from actual long-term pumping data. It is considered inappropriate to conduct a pumping test without completing a step-drawdown test, particularly without existing knowledge of the pumping characteristics of the pumping well. Constant rate pumping tests that incorporate multiple observation wells may cost several tens or even hundreds of thousands of dollars to complete, in particular when wells are installed as part of the test. Experts should be consulted during the scoping, project planning, and technical design phase to ensure that the test is conducted in a technically sound and cost-effective manner. Key members of the field team should possess extensive experience conducting aquifer tests. The following design components must be evaluated prior to completion of a pumping test:

> Duration of Pumping Test - Confined Aquifer. Confined aquifers respond to pumping relatively quickly due to small storativity values. A pumping test for a confined aquifer should be conducted over a period of 24 hours (one day) to achieve steady state conditions. It is noted that there is no fixed time for pumping tests. Preliminary plotting of data in the field may indicate how the aquifer is responding, thus determining the duration of the test.
>
> Duration of Pumping Test - Unconfined Aquifer. The cone of depression that results from pumping expands much more slowly for unconfined aquifers prior to reaching a steady state. The generally accepted minimum duration pumping test for an unconfined aquifer is therefore 72 hours (three days).

Discharge Rate. The discharge rate should be based on the results of the step-drawdown testing program. The specific capacity calculated from the step test should be used to estimate the desired drawdown and pumping rate. Because of the uncertainty in the step test calculations, a level of safety should be factored into the desired drawdown level to ensure that the water level is not drawdown to the pumping level. If the water level is lowered to the pumping level, the test should be terminated immediately (although recovery data should be collected until the aquifer recovers to static conditions).

Frequency of Water Level Measurements. Water levels should be recorded electronically using a continuous pressure transducers and a data logger, and manually using a conductivity-based water level indicator. Following the "logarithmic data recording cycle", the pressure transducer can be set to record water levels initially every minute. Time intervals for manual measurements of drawdown are presented in the table below:

Elapsed Time (minutes)	Time Intervals (minutes)
0-10	0.5
10-15	1
15-60	5
60-120	30
120-end of test	60

Control Points. It is recommended for control purposes that water levels be monitored in a well located at a distance beyond the area of influence of the test. The well must be screened within similar hydrostratigraphic units and the same side of boundaries as wells in the test. It is also recommended to monitor barometric pressure during the test. Data from a local airport or transducer will suffice.

Background Water Level Data. It is useful to monitor water levels in the proposed pumping well and observation wells for a week prior to conducting the pumping test. The background data provides the mechanism to evaluate marine and earth tides, barometric influences, temperature influences, etc.

Background Pumping Data. It is extremely important to understand regional or site-specific groundwater pumping to evaluate well interference, relic drawdown, etc. If a production zone is used for the pumping test, a well canvass should be completed to determine aquifer groundwater uses, and remediation systems, such as nearby soil vapor extraction systems, noted.

Collection of Water Samples. In many cases, groundwater should be collected during the pumping test to gather data required for treatability testing. At a minimum, groundwater should be monitored during pumping for pH, temperature, electrical conductivity, and turbidity.

Miscellaneous. Precipitation events must be recorded in the field notes, including time of onset, duration, and rainfall total. Barometric readings should be checked and recorded hourly. For shallow zone wells, the passing of heavy equipment or trains should be noted on the field logs. For tidal aquifers, a tidal gauge should be included in the study. Continuous recording of tidal levels is strongly recommended to assess tidal influences of the test.

2.4.2 Constant Rate Pumping Test Methods

The description of the pumping test outlined below assumes several observation wells will be used in the test. Continuous data logging equipment should be used wherever possible, although manual backup measurements should also be taken periodically. All of the data loggers should be synchronized to the correct day, date, and time. All project team members must synchronize their watches to the correct time datum.

1. Remove the well head expansion cap from all observation wells and piezometers, as well as the pumping well. Allow all wells to equilibrate to atmospheric conditions.

2. Record the static water level using a conductivity-based water level indicator. Sound the well. Note potential sediment at bottom.

3. Determine the appropriate depth of the transducer for the pumping well. A 50-psi transducer (capable of measuring 106 feet of head change) is well suited for the pumping well. The transducer should be targeted for a level 3 to 5 feet above the pumping level whenever possible to minimize interference with the pump. In some instances, installation of the transducer below the pump may be required. Care must be taken to not entangle the transducer with the pump, or to lower the transducer into sediment at the bottom of the well. Affix duct tape to transducer cable to indicate the target depth below TOC.

4. The pump should be set in the well at the desired pumping level. This is usually the screened interval for shallow wells (<100 feet total depth). For deeper wells, the pumping depth only needs to be greater than the anticipated drawdown (it is wise to be conservative and consider a margin of error). It may be cost-effective to hire a pumping subcontractor to operate the pumps, discharge lines, etc., especially for high flow-rate, long-term tests. Contaminated groundwater discharged from the well may require storage in portable tanks or treatment prior to disposal. All disposal options and permitting must be in place prior to conducting the test. A water disposal option should be chosen that does not impinge on the groundwater flow system during the test via infiltration recharge, etc.

5. Lower the transducer to the target depth in the pumping well. The transducer and transducer cable must hang plumb in the well to minimize entanglement with the pump discharge pipe/hose. Duct tape the transducer cable to an immovable object such as the TOC, Christy box, or stovepipe. Allow the well to equilibrate to static water levels. Install pressure transducers in all of the monitoring wells included in the test in a manner similar to that described above. In early all applications, a 10-psi transducer (highly accurate over a 23-foot range) is ideal for monitoring drawdown in observation wells.

6. Connect the pressure transducers that have been installed in each well to a continuous data recorder. A single, multi-channel data logger may suffice if observation wells are near one another, or several "remote" loggers may be required for wells separated by great distances. Input the required transducer parameters and other test parameters in the data logger per the specification in the manual. The data logger will typically prompt the user to record water levels below the TOC or surface. Surface refers to a static water level datum. The instrument is therefore "referenced" or "zeroed" to the either a static water level or to a value input by the operator. Water levels below static water level will be recorded as negative values. For pumping test purposes, water levels can be recorded relative to either "TOC" or "surface.” Referencing to "surface mode" minimizes mistakes in the field. Additionally, nearly all data reduction techniques evaluate drawdown, not absolute water levels. An accurate record of all input parameters and field observations must be included in a field log.

7. "Zero" the pressure transducer/data logger to static water levels (or, alternatively, enter the TOC value for each well). Confirm static levels (or TOC-adjusted values) with a water level indicator. All data loggers must be synchronized to a common day-date-time (plus/minus 15 seconds). Because all loggers are synchronized, it is not necessary to trigger each logger simultaneously. Remote data loggers may not show an immediate drawdown response, and it is acceptable to trigger these loggers prior to starting the pump and simply allow them to run. An alternative is to set each logger on the "delayed

start mode" set to begin at a predetermined time (i.e., when the pump is started). Field experience indicates that this requires an extremely high level of coordination and timing. For the pumping well and for observation wells close by the pumping well, it is advantageous to record the early time data at frequent intervals. This is best accomplished using the "logarithmic data recording mode" for each transducer, with manual triggering of each data logger at the time the pump is started. This may require a project team member per well at the beginning of the test.

8. TEST START-UP. This is the critical step. Once the pump is started, simultaneously the desired constant pumping rate needs to be established, well gauging and/or transducers/data loggers started, and note collection begins. If problems occur during test startup that require restarting the test, then time must be allowed for static conditions to be achieved before restart. Therefore, it is imperative that logistics and personnel requirements be well planned prior to startup.

   On a predetermined count, one person must simultaneously start the pump and stabilize the discharge rate to the desired gpm (determined from a step test). As drawdown increases, the required pumping head also increases and the pump control will have to be adjusted accordingly. Other project team members must simultaneously trigger the data loggers not yet running. At the same time, another team member should begin recording water levels as rapidly as possible in the pumping well (see frequencies above). It helps to have the data table constructed with water level time intervals predetermined. The data recorded by the transducers and data logger can be viewed following completion of the logarithmic data recording cycle (approximately 2-3 minutes). Water levels recorded by the transducer/data logger system should be similar to the manually recorded water levels. It is beneficial to plot the time and drawdown data in the field to ensure that the pumping rate and the drawdowns are adequate. The first couple of hours of the pumping test can be very hectic. It is recommended that "more" rather than "less" project team staff be on site to assist in the early stages of the test. The size of the field team can be greatly reduced following the initial few hours of the test.

9. Monitoring Water Levels and Discharge Rates. Water levels should be monitored on the frequency detailed above. The discharge rate should be monitored at least every 30 to 60 minutes, and recorded on a field log.

2.5 RECOVERY TESTS

A recovery test should always be completed following either a step-test or a constant rate pumping test. As stated above, a recovery test is invaluable if the pumping test is performed without the use of piezometers or observation wells to evaluate potential borehole storage effects in the pumping well. Additionally, residual drawdowns are more reliable than drawdowns measured during pumping due to difficulties in the field of maintaining absolutely constant discharge from a pumping well. However, if the aquifer conditions are not ideal, the recovery solution is less accurate and difficult to evaluate. When specifying measurement of recovery data for the pumped well, a check valve must be installed in the pump to prevent backflow of water in the discharge line to the well. This will ensure that water level rise gauged is related to formational response only.

2.5.1 Recovery Test Methods

When the pump is shut down following a pumping test, water levels in the pumping well and observation wells will begin to rise. This rise is known as residual drawdown. As with other types of aquifer tests, the relationship between discharge rate, time, and drawdown measured during the step test can be used in well-flow equations and corresponding "recovery equations" to determine the aquifer transmissivity and storage coefficient, and well characteristics.

1. Complete a step-test or constant rate pumping test in the manner detailed above.
2. This is the critical step. On a predetermined count, simultaneously turn off the pump, "Step" the data logger, and manually record recovery (residual drawdown) data. The early time data should be recorded using the "log" data recording mode (high data logging frequency). Continue recording the recovery data until the water level returns to static water levels (or nearly so). The test is completed.
3. This is an important step. Carefully download the field data to a PC computer. Obtain a hard copy and a master electronic copy to be stored in project records.

2.6 QUALITY CONTROL

This section discusses applicable quality control measures to be used to ensure and evaluate the effectiveness of the test.

2.6.1 Data Collection

Field parameters and manual well gauging data will be recorded on field forms. Water levels will be gauged and recorded, then re-gauged to check the recorded value. An aquifer test data collection form is attached to this SOP. The form for the collection of water chemistry data is attached to TIMET SOP #103 “Groundwater Sampling Using Micropurge.”

2.6.2 Duration of Pumping Test

The duration of pumping tests must be designed on a test by test basis. However, for single-well test drawdown and recovery tests, the pumping period will be long enough to overcome the storage effects of water in the well casing. This is referred to as the critical time.

At a minimum, single well pumping tests shall be conducted for a length of time such that the critical time is surpassed. This is to ensure that drawdown response is formational and is not reflective of casing storage. Critical time is defined by Schafer (1978) as:

$$t_c = \{(375R_w^2)/T\}1440$$

where: t_c = Critical time in minutes
R_w = Casing radius
T = Transmissivity (gallons per day per foot)

Transmissivity can be approximated from specific capacity data (Driscoll 1986):

$$T = 2000Q/s$$

Where: Q = Pumping rate (gpm)
s = Drawdown in well (ft)

2.6.3 Maintaining Constant Pumping Rate

Totalizing flow meters should be utilized to measure and maintain discharge rate. Totalizing meters allow instantaneous reading of flow rate as well as cumulative volume of water pumped over the duration of the test, which in turn allows calculation of average pumping rate as total volume pumped (gallons) divided by total time (minutes).

Gate valves placed in the discharge line can be used to maintain a steady discharge rate; however, valves can drift and flow rates vary accordingly. If the pump head is significantly greater than the total dynamic head it pumps against, then an accurate way of maintaining constant discharge is with a Dole valve. A Dole valve is basically an orifice that yields constant discharge as long as the upstream pressure does not vary significantly.

When using an amperage-based pump controller, the discharge is controlled by varying the amperage to maintain flow rate. However, drawdown in the pumped well changes the head with time, and hence the flow rate can drift downward in response to drawdown. Therefore, maintaining constant amperage will not necessarily maintain a constant discharge rate.

Because the potential for drift in discharge is virtually guaranteed, it is advisable to keep close track of discharge rates, and to bucket gauge periodically to verify accuracy of meter readings. Bucket gauging is accomplished by timing the period necessary to fill a container (i.e., drum, pail, etc.) of known volume. Volume of container (gallons) divided by time (minutes) yields an estimate of discharge.

2.6.4 Correction of Pumping Test Data

Tidal influences, recharge, discharge and barometric effects can all influence water levels in wells during pumping tests. At the Plant Site, only barometric effects, and possibly discharge from groundwater corrective actions at Tronox, are anticipated to effect data. Single well tests of short duration typically do not last long enough for external influences in water levels to be an issue. However, if water levels do not recover to 95% or better, external influences may have affected the test.

In order to determine if barometric pressure fluctuations or nearby ground extraction is influencing water levels, wells should be gauged throughout the pump test period in areas far enough from the pumping test to not be affected by pumping, and between the pumping test and nearby point of diversion to evaluate nearby pumping effects. These locations will be specified at the work plan level for specific tests.

If the far-field gauging data indicate external influences on water levels, corrections can be made to the data prior to analysis. Techniques available are discussed in Kruseman and de Ridder (1991).

2.6.5 Logistical Considerations

Disruptions to long duration pumping tests (i.e, half-day to multiple day tests) can violate underlying assumptions of constant rate tests, and cause undesired corrections and/or analysis of only partial data sets. These disruptions can be related to factors outside the field personnel's control (e.g., electrical power outages). However, common causes of disruptions to pumping or data collection are listed below for planning purposes.

1. Insufficient gasoline on hand when using a gasoline powered generator. Start the test with sufficient gasoline on hand to power the generator until pumping has proceeded to the point that data collection needs have lessened.
2. Insufficient capacity to store discharge groundwater. If discharged water must be stored and characterized, ensure sufficient capacity or treatment is available within the time constraint of the test to handle the water. Specific capacity or development should allow reasonable estimation of storage capacity required before starting the test.
3. Make sure pressure transducers are fully charged and functional prior to starting the test.
4. Make sure that water level indicators have charged batteries and have back up batteries on hand.
5. If a personal computer is available, it may be possible to plot and maintain time-drawdown and distance-drawdown data to ensure the test and data collection is progressing as envisioned and designed. Plots of barometric pressure maintained during the test may reflect deviations in plotted well levels if external factors are affecting data.

2.7 DATA ANALYSIS METHODS

This SOP has focused on the actual conduct of aquifer tests. However, it is also important for the project team to determine which methods will be used for data analysis prior to completion of the test in the field. Many aquifer analysis methods have assumptions that may limit or even invalidate the use of certain types of aquifer test methods. A brief list of test methods is provided below, although please note that numerous other methods are available. Experts should be consulted in the design phase (not after the field program) to ensure aquifer tests that consider underlying assumptions, boundary conditions, and data collection need so that site hydrogeologic condition are best reflected.for technically difficult or potentially risky aquifer studies (nearly always the case).

2.7.1 Slug Testing Data Analysis Methods

- Bouwer-Rice, 1976, Curve Fitting Method (unconfined, steady state)
- Hvorslev Straight Line Method (point piezometer)
- Cooper, et al., 1967, Curve Fitting (confined, unsteady state, fully penetrating)
- Ferris-Knowles Estimation

2.7.2 Step Drawdown Test Methods

- Birsoy-Summers Method (confined)
- A modified Cooper-Jacob Method (1946) (confined)

2.7.3 Constant Rate Pumping Tests and Recovery Tests Methods

- Cooper-Jacob Straight Line Approximation (confined, unsteady state)
- Theis (1935) Curve Matching Method (unsteady state, confined, pumping or recovery)
- Neuman (1975) Curve Fitting Method (unconfined, unsteady state, delayed response)
- Hantush-Jacob (1955) Method (leaky, unsteady state, no storage in aquitards)
- Hantush (1960) Method (leaky, unsteady state, with storage in aquitards
- Thiem (1906) Method (steady state, confined)
- Neuman and Witherspoon, 1972 (Analyses of Leaky Aquifers).
- Moench, A.F., 1996. Flow to a Well in a Water-Table Aquifer: An Improved Laplace Transform Solution. Ground Water, vol. 34. No. 4, pp. 593-596

DISCLAIMER
This SOP provided general guidance for TIMET contractors and subcontractors for technical issues addressed during environmental site investigation and remediation activities. It is noted, however, that each site and project is unique and these guidelines are not a substitute for common sense and good management practices based on professional training and experience. In addition, individual contract terms may affect the implementation of this SOP. TIMET contractors reserve the unrestricted right to change, modify or not apply these guidelines in their sole, complete, and unrestricted discretion to meet certain circumstances, contractual requirements, site conditions, or job requirements. Any deviations from this written SOP will be documented and reported with test data.

ATTACHMENT

Field Aquifer Test Data Collection Form

PROJECT NAME ____________________

PROJECT NO. ____________________

WELL OR HOLE NO. ____________________

PAGE ________ OF ________

AQUIFER TEST DATA

PUMP ON DATE ________ TIME ________	HOW W.L.'s MEASURED ____________________	HOW Q MEASURED ____________________
PUMP OFF DATE ________ TIME ________	DISTANCE FROM PUMPING WELL ____________________	DEPTH OF PUMP/AIRLINE ____________________
DURATION OF AQUIFER TEST ____________________	MEASURING POINT ____________________	TYPE OF TEST ____________________
RECORDED BY ____________________	ELEVATION MEASURING POINT ____________________	PREVIOUS PUMPING ____________________

TIME					WATER LEVEL DATA SWL= ________				DISCHARGE DATA		COMMENTS
DATE	CLOCK TIME	PUMPING ELAPSED TIME t	RECOVERY ELAPSED TIME t'		WATER LEVEL DEPTH BELOW DATUM	WATER LEVEL ELEVATION (FEET)	WATER LEVEL CHANGE (FEET)		DISCHARGE RATE (gpm)		

1.0 INTRODUCTION

Micropurge sample collection provides a method of minimizing increased colloid mobilization by removing water from the well at the screened interval at a rate that preserves or minimally disrupts steady-state flow conditions in the aquifer. During micropurge sampling, groundwater is discharged from the aquifer at a rate that the aquifer will yield without creating a cone of depression around the sampled well. Research indicates that colloid mobilization will not increase above steady-state conditions during low-flow discharge. Therefore, the collected sample is more likely to represent steady-state groundwater chemistry.

1.1 PURPOSE

The purpose of this Standard Operating Procedure (SOP) is to describe the procedures to be used to collect a groundwater sample from a well using the micropurge technology. The following sections describe the equipment to be used and the methods to be followed to promote uniform sample collection techniques by field personnel that are experienced in sample collection and handling for environmental investigations.

1.2 SCOPE

This SOP applies to groundwater sampling using the micropurge technology.

1.3 DEFINITIONS

Colloid: Suspended particles that range in diameter from 5 nanometers to 0.2 micrometers.

Dissolved oxygen: The ratio of the concentration or mass of oxygen in water relative to the partial pressure of gaseous oxygen above the liquid which is a function of temperature, pressure, and concentration of other solutes.

Flow-through cell: A device connected to the discharge line of a groundwater purge pump that allows regular or continuous measurement of selected parameters of the water and minimizes contact between the water and air.

pH: The negative base-10 log of the hydrogen-ion activity in moles per liter.

Specific conductance: The reciprocal of the resistance in ohms measured between opposite faces of a centimeter cube of aqueous solution at a specified temperature.

Turbidity: A measurement of the suspended particles in a liquid that have the ability to reflect or refract part of the visible portion of the light spectrum.

1.4 REFERENCES

Attached are the following applicable American Society for Testing and Materials (ASTM) standard practices and guidelines related to field measurement of groundwater samples by various methods. The ASTM standards listed are considered an integral part of this SOP, and must be attached.

- D-1293-99(2005) Standard Test Methods for pH of Water
- D888-05 Standard Test Methods for Dissolved Oxygen in Water
- D-1125 Standard Test Methods for Electrical Conductivity and Resistivity of Water
- D-1889 Standard Test Methods for Turbidity in Water

Puls, R. W. and M. J. Barcelona. 1996. Low-Flow (Minimal Drawdown) Ground-Water Sampling Procedures. U.S. Environmental Protection Agency. Office of Research and Development. EPA/540/S-95/504. April.

1.5 REQUIREMENTS AND RESOURCES

The following equipment is required to complete micropurge sample collection:

- Water level indicator
- Adjustable flow rate pump (bladder, piston, peristaltic, or impeller)
- Discharge flow controller
- Flow-through cell
- pH probe
- Dissolved oxygen (DO) probe
- Turbidity meter
- Specific conductance (SC) probe (optional)
- Temperature probe (optional)
- Meter to display data for the probes
- Calibration solutions for pH, SC, turbidity, and DO probes, as necessary
- Container of known volume for flow measurement or calibrated flow meter

- Data recording and management system

2.0 PROCEDURE

The following procedures and criteria were modified from the U. S. Environmental Protection Agency guidance titled "Low-Flow (Minimal Drawdown) Ground-Water Sampling Procedures" (Puls and Barcelona 1996). This reference may be consulted for a more detailed description of micropurge sampling theory.

Micropurging is accomplished with low-discharge rate pumps, such as bladder pumps, piston pumps, controlled velocity impeller pumps, or peristaltic pumps. Bailers and high capacity submersible pumps are not considered acceptable micropurge sample collection devices. The purged water is monitored (in a flow-through cell or other constituent monitoring device) for chemical and optical parameters that indicate steady state flow conditions between the sample extraction point and the aquifer. Samples are collected when steady state conditions are indicated.

2.1 EQUIPMENT CALIBRATION

Prior to sample collection, the monitoring equipment used to measure pH, DO, turbidity, and SC should be calibrated or checked according to manufacturer's directions. Typically, calibration activities are completed at the field office at the beginning of sampling activities each day. The pH meter calibration should bracket the pH range of the wells to be sampled (acidic to neutral pH range [4.00 to 7.00] or neutral to basic pH range [7.00 to 10.00]). The DO meter should be calibrated to one point (air-saturated water) or two points (air-saturated water and water devoid of all oxygen). The SC meter cannot be calibrated in the field. It is checked against a known standard (typical standards are 1, 10, and 50 millimhos per centimeter at 25°C). The offset of the measured value of the calibration standard can be used as a correction value. All calibration data should be recorded on the Micropurging Groundwater Sampling Data Sheet attached to this SOP or in a logbook.

2.2 WELL PURGING

The well to be sampled should be opened and groundwater in the well allowed to equilibrate to atmospheric pressure. Equilibration should be determined by measuring depth to water below the marked reference on the wellhead (typically the top of the well casing) over two or more 5-minute intervals. Equilibrium conditions exist when the measured depth to water varies by less than 0.01 foot over two consecutive readings. Total depth of well measurement should be made before installing the sample collection equipment.

A new or previously decontaminated portable sample collection device should be placed within the well. The intake of the device should be positioned at the midpoint of the well screen interval. The device should be installed slowly to minimize turbulence within the water in the casing and mixing of stagnant water above the screened interval with water in the screened interval. Following installation, the flow controller should be connected to the sample collection device and the flow-through cell connected to the outlet of the sample collection device. The calibrated groundwater chemistry monitoring probes should be installed in the flow-through cell.

The controller for the sample collection device should be connected to the sample collection device. The flow-through cell should be connected in line to the discharge tube, and the probes installed in the flow-through cell.

The controller should be activated and groundwater extracted (purged) from the well. The purge rate should be monitored, and should not exceed the capacity of the well. The well capacity is defined as the maximum discharge rate that can be obtained with less than 0.1 meter (0.3 foot) drawdown. Typically, the discharge rate will be less than 0.5 liters per minute (L/min) (0.13 gallons per minute). The maximum purge rate should be adjusted to achieve minimal drawdown.

Water levels, effluent chemistry, and effluent flow rate should be continuously monitored while purging the well. Purging should continue until the measured chemical and optical parameters are stable. Stable parameters are defined as monitored chemistry values that do not fluctuate by more than the following ranges over three successive readings at 3-minute intervals: +/-0.1 pH unit; +/-3 percent for SC; and +/-10 percent for turbidity and DO. Purging will continue until these stabilization criteria have been met or three well casing volumes have been purged. If three casing volumes of water have been purged and the stabilization criteria have not been met, a comment should be made on the data sheet that sample collection began after three well casing volumes were purged. The final pH, SC, turbidity, and DO values will be recorded. All data should be recorded on the Micropurging Groundwater Sampling Data Sheet attached to this SOP or in a logbook.

2.3 SAMPLE COLLECTION

Following purging, the flow through cell shall be disconnected, and groundwater samples collected directly from the discharge line. Discharge rates should be adjusted so that groundwater is dispensed into the sample container with minimal aeration of the sample. Samples collected for volatile organic compound analysis should be dispensed into the sample container at a flow rate equal to or less than 100 milliliters per minute. Samples should be preserved and handled as described in the investigation field sampling plan or quality assurance project plan.

DISCLAIMER
This SOP provided general guidance for TIMET contractors and subcontractors for technical issues addressed during environmental site investigation and remediation activities. It is noted, however, that each site and project is unique and these guidelines are not a substitute for common sense and good management practices based on professional training and experience. In addition, individual contract terms may affect the implementation of this SOP. TIMET contractors reserve the unrestricted right to change, modify or not apply these guidelines in their sole, complete, and unrestricted discretion to meet certain circumstances, contractual requirements, site conditions, or job requirements.

TIMET Groundwater Monitoring Program - Micropurge Gauging and Sampling Sheet

TIMET

Well ID _________ DATE ________

Field Personnel ______________________________

Sampling Organization _____***TIMET***_____

Field observations:(weather, well conditions etc.) _____

Surveyed Measuring Point (MP): *TOC* Elevation[1] :

Depth to top[1] ________/_____ bottom of screen (below MP)

Pump Intake at ___________ (ft. below MP)

Purging Device - pump type ________________________________

Pump Model ___________ volume (bladder plus tubing) ________

Parameter tolerences (%):		**3%**	**+/-10%**	**na**	**+/- 0.1**	**+/-10%**	**NOTE: DRAWDOWN LIMIT = 0.3 FT OR 3.6-IN.**				
Values:							**DRAWDOWN SETPOINT = SWL + 0.3 FT**				
CLOCK TIME (24 HR)	STATIC WATER DEPTH (SWL)	TEMP ^{0}C ^{0}F ^{0}K	SPECIFIC COND. (µS/cm)	DO (Mg/L)	ORP (Eh)	pH	TURBIDITY (NTU)	REFILL TIMER SETTING (secs)	DISCH. TIMER SETTING (secs)	PRESS. SETTING (PSI)	FLOW RATE (m/Min)	mp10/mp15 Digital Control ID setting

Well information

Dedicated pump (Y / N)

Stick-up or flush mount (circle)

Note: measurements from MP

Static WL ________

drawdown setpoint ________

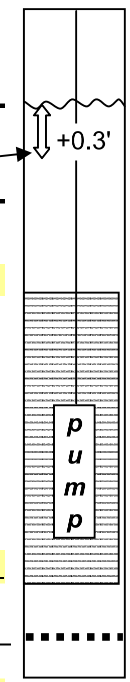
top of screen ______

Pump intake[2] _______ (depth from MP)

bottom of screen ____

Measured total depth from TOC _____

Blank casing (Y/N)



RECORDED PARAMETERS

INI. DEPTH TO WATER: _________ (static WL with out pump in)

DEPTH TO WATER: _______(W/ PUMP INSTALLED)

TIME AT START OF SAMPLING : _______

DEPTH TO WATER AT COMPLETION OF SAMPLING: ________

TIME AT COMPLETION OF SAMPLING : _______

CUMULATIVE VOLUME PURGED: ________

NOTES / COMMENTS: ____________________

Note 1: Obtain data from Table 1, Well Construction Summary, in Groundwater Monitoring Well Network Technical Memorandum
Shaded cells should be filled in prior to going into the field

Note 2: Pump intake should be set 4 feet +/-0.5 ft from the static water level measured prior to placement of pump

1.0 INTRODUCTION

Porous media, such as concrete, adsorbs liquids impacted with polychlorinated biphenyls from discharges and spills. Wipe sampling and coring are the two primary methodologies for collecting representative samples of this medium.

1.1 PURPOSE

This Standard Operating Procedure (SOP) is a general reference for the proper equipment and techniques for concrete sampling. These techniques should be followed whenever applicable, although site-specific conditions or project-specific plans may require adjustments in methodology.

1.2 SCOPE

The purpose of these procedures is to enable the user to collect representative and defensible wipe samples and to facilitate planning of the field sampling effort.

2.0 WIPE SAMPLING GUIDELINES

Collection of wipe samples will follow the guidelines as set forth in 40 CFR 761.123 Standard Wipe Test.

2.1 WIPE SAMPLE COLLECTION METHOD

Prior to sampling, the area should be cleared of any debris or potential cross-contamination from other activities. One wipe sample should be taken from a 100-square centimeter (cm) surface area (10 cm by 10 cm) at each point for sample collection. The surface should be flat. Wipes are usually composed of filter paper, gauze or glass wool. Wipe samples should be collected from flat, smooth surface areas of at least 10 cm by 10 cm. Wipe samples should be collected from areas expected to be representative of contaminant distribution, such as areas with visible staining.

Samples collected for volatile organic analyses should be collected using a wipe that is wet with the appropriate solvent for the analyte to be collected. Samples collected for metals analysis should be collected using a wipe that is wet with deionized water. One 10-cm square template should be used for each sample location. With the sampling media, wipe downward and then across the template.

Upon completion of the sample collection, the wipe sample is placed in a glass jar and the appropriate preservative is added to the sample container. The wipe samples shall be placed in separate containers and stored in a cooler packed with ice for transportation to the laboratory.

2.2 SAMPLE CONTAINERS

A complete set of sample containers should be prepared by the laboratory prior to going into the field. The laboratory should provide the proper containers with the required preservatives. The laboratory's quality manual should provide a complete description of the procedures used to clean and prepare the containers. The containers should be labeled in the field with the date, sample identification, project name, collectors' name, time of collection, parameters to be analyzed, and preservative. The sample containers should be kept in a cooler (at zero plus or minus 2 degrees centigrade) until they are received by the laboratory. One cooler should be used to store the unfilled bottles and another to store the samples. All sample bottles and equipment will be kept away from fuels and solvents.

When wipe samples are to be analyzed for volatile organic analyses, samples will be carefully collected in a manner than minimizes volatilization.

3.0 CONCRETE CORE

The collection of concrete core samples are specified in 40 CRF 761.286 to be a minimum of 1 inch in diameter (≤2 centimeters and ≤3 centimeters) and a maximum of 3 inches long (7.5 centimeters) from within a sampling grid.

EPA Region I developed an SOP for sampling concrete which will be followed in all TIMET field events unless otherwise noted in the project-specific sampling and analysis plan (see attached).

DISCLAIMER
This SOP provided general guidance for TIMET contractors and subcontractors for technical issues addressed during environmental site investigation and remediation activities. It is noted, however, that each site and project is unique and these guidelines are not a substitute for common sense and good management practices based on professional training and experience. In addition, individual contract terms may affect the implementation of this SOP. TIMET contractors reserve the unrestricted right to change, modify or not apply these guidelines in their sole, complete, and unrestricted discretion to meet certain circumstances, contractual requirements, site conditions, or job requirements.

REGION I, EPA-NEW ENGLAND

DRAFT
STANDARD OPERATING PROCEDURE
FOR SAMPLING CONCRETE IN THE FIELD

U.S. EPA-NEW ENGLAND
Region I
Quality Assurance Unit Staff
Office of Environmental Measurement and Evaluation

Prepared by:	**Alan W Peterson** **Quality Assurance Chemist**	**Date:**	12/30/97
Reviewed by:	**Andrew Beliveau** **Senior Technical Specialist**	**Date:**	12/30/97
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Region I, EPA New England

Standard Operating Procedure for Sampling Concrete in the Field

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Region I, EPA New England

Standard Operating Procedure for Sampling Concrete in the Field

1.0 Scope and Application

The following Standard Operating Procedure (SOP) describes a concrete sampling technique which uses an impact hammer drill to generate a uniform, finely ground, powder which is easily homogenized, extracted and analyzed. This procedure is primarily geared at providing enough sample for one or two different analyses at a time. That is, the time required to generate sufficient sample for a full suite of analyses may be impractical. The concrete powder is suitable for all types of environmental analyses, with the exception of volatile compounds, and may be analyzed in the field or at a fixed laboratory. This procedure is applicable for the collection of samples from concrete floors, walls, and ceilings.

The impact hammer drill is far less labor intensive than previous techniques using coring devices, or hammers and chisels. It allows for easy selection of sample location and sample depth. Not only can the project planner control the depth to sample into the concrete, from surface samples (0 - ½ inch) down to a core of the entire slab, but the technique can also be modified to collect samples at discrete depths within the concrete slab.

Another issue with concrete sampling is the fact that the amount of time spent drilling translates into the weight of sample produced. Thus, to maximize sampling time, it is important to know the minimum amount of sample required for each analysis. To do this, the project planner should take the following steps: 1) Use the Data Quality Objective (DQO) process and familiarity with the site to develop the objectives of the sampling project and the depth(s) of sample to be collected. 2) Review the site history and any previous data collected to determined possible contaminants of concern. 3) Establish the action levels for those possible contaminants and determine the appropriate analytical methods (both field and/or fixed laboratory) to meet the DQOs of the project. 4) Based on the detection limits of these methods, determine the amount of sample required for each analysis and the total sample weight require for each sample location (including quality control samples).

As with any environmental data collection project, all aspects of a concrete sampling episode should be well thought out, prior to going out in the field, and thoroughly described in a Quality Assurance Project Plan (QAPP). The QAPP should clearly state the DQOs of the project and document a complete Quality Assurance/Quality Control program to reconcile the data generated with the established DQOs. For more information on these subjects, refer to EPA documents QA/R-5, EPA Requirements for Quality Assurance Project Plans for Environmental Data Operations, and QA/G-4, Guidance for the Data Quality Objective Process.

2.0 Method Summary

A one-inch diameter carbide drill bit is used in a rotary impact hammer drill to generate a fine concrete powder suitable for analysis. The powder is placed in a sample container and homogenized for field or fixed laboratory analysis. The procedure can be used to sample a single depth into the concrete, or may be modified to sample the concrete at distinctly different depth zones. The modified depth sampling procedure is designed to minimize any cross contamination between the sampling zones. If different sampling depths are required, two different diameter drill bits and a vacuum sampling apparatus are employed.

3.0 Health and Safety

Eye and hearing protection are required at all times during sample drilling. A small amount of dust is generated during the drilling process. Proper respiratory protection and/or a dust control system must be in place at all times during sampling.

4.0 Interferences and Potential Problems

Since this sampling technique produces a finely ground uniform powder, physical matrix effects from variations in the sample consistency (i.e., particle size, uniformity, homogeneity, and surface condition) are minimized. Matrix spike analysis of a sample is highly recommended to monitor for any matrix related interferences.

As stated in Section 1.0 above, this sampling procedure is not recommended for volatile organic compound (VOC) analysis. The combination of heat generated during drilling and the exposure of a large amount of surface area will greatly reduce VOC recovery. If low boiling point semi-volatile compounds (i.e., naphthalene) are being analyzed, then the drill speed should be reduced to minimize heat build-up.

5.0 Equipment and Supplies

5.1 Single Depth Concrete Sampling

5.1.1 Rotary impact hammer drill
5.1.2 1-inch diameter carbide drill bits
5.1.3 Stainless steel scoopulas
5.1.4 Stainless steel spoonulas (for collecting sample in deeper holes, >2-inches)
5.1.5 Rectangular aluminum pans (to catch concrete during wall and ceiling sampling)
5.1.6 Gasoline powered generator (if alternative power source is required)

5.2 Multiple Depth Sampling (in addition to all the above)

5.2.1 ½ inch diameter carbide drill bits
5.2.2 Vacuum/sample trap assembly (see Section 7.2 and Figure 1)

5.2.2.1 Vacuum pump
5.2.2.2 2-hole rubber stopper
5.2.2.3 Glass tubing (to fit stopper)
5.2.2.4 Large glass test tubes, or Erlenmeyer flasks, for sample trap (several are suggested)
5.2.2.5 Polyethylene tubing for trap inlet (Tygon tubing may be used for the trap outlet)
5.2.2.6 Pasture pipets
5.2.2.7 Pipe cleaners
5.2.2.8 In-line dust filter (glass fiber filter, or equivalent)

6.0 Sample Containers, Preservation, and Storage

Concrete samples must be collected in glass containers for organic analyses, and may be collected in either glass or plastic containers for inorganic analyses. In general, a 2-ounce sample container with Teflon-lined cap (wide-mouth jars are preferred) will hold sufficient volume for most analyses. A 2-

ounce jar can hold roughly 90 grams sample. Note, samples which require duplicate and/or matrix spike/matrix spike duplicate analyses may require a larger sample container, or additional 2-ounce sample containers.

Organic samples are to be shipped on ice and maintained at 4°C (± 2°C) until the time of extraction and analysis. Inorganic samples may be shipped and stored at room temperature. Refer to 40 CFR Part 136 for guidelines on analysis holding times.

To maintain sample integrity, chain-of-custody procedures must be implemented at the time of sampling to 1) document all sample locations and associated field sample identification numbers, 2) document all quality control samples taken, including field duplicates, split samples for confirmatory analyses, and PE samples, and 3) document the transfer of field samples from field sampler to field chemist or fixed laboratory.

7.0 Procedure

7.1 Single Depth Concrete Sampling

Lock a 1-inch diameter carbide drill bit into the impact hammer drill and plug the drill into an appropriate power source. (A gasoline generator will be needed if electricity is not available.) For easy identification, sample locations may be pre-marked using a crayon or a non-contaminating spray paint. (Note, the actual drilling point must not be marked.) Depending on the appearance of the sample location, or the objectives of the sampling project, it may be desired to wipe the concrete surface with a clean dry cloth prior to drilling. All sampling decisions of this nature should be noted in the sampling logbook. Begin drilling in the designated location. Apply steady even pressure and let the drill do the work. Applying too much pressure will generate excessive heat and dull the drill bit prematurely. The drill will provide a finely ground concrete powder that can be easily collected, homogenized and analyzed. Having several decontaminated impact drill bits on hand will help expedite sampling when numerous sample locations are to be drilled.

Sample Collection

A ½-inch deep hole (using a 1-inch diameter drill bit) generates about 10 grams of concrete powder. Based on this and the action levels for the project, determine the sampling depth, and/or the number of sample holes to be composited, to generate sufficient sample volume for all of the required analyses. (Note, with the absorbency of concrete, a ½-inch deep hole can be considered a surface sample.)

A decontaminated stainless steel scoopula can be used to collect the sample. The powder can either be collected directly from the surface of the concrete and/or the concrete powder can be scraped back into the hole and the less rounded back edge of the scoopula can be used to collect the sample. For holes greater than 2-inches in depth, a stainless steel spoonula will make it easier to collect the sample from the bottom of the hole.

To ensure collection of a representative sample when multiple analyses are required, a concrete sample should always be collected and homogenized in a single container and then divided up into the individual containers for the various analyses or split samples. This is particularly important when sample holes are deep, or when several holes are drilled adjacent to each other to form a sample composite.

Wall and Ceiling Sampling

A team of two samplers will be required for wall and ceiling sampling. The second person will be needed to hold a clean catch surface (i.e., an aluminum pan) below the drill to collect the falling powder. For wall samples, a scoopula, or spoonula, can be used to collect remaining concrete powder from within the hole. For ceiling holes, it may be necessary to drill the hole at an angle so the concrete powder can fall freely in the collection plan (and avoid falling on the drill). Another alternative might be to use the chuck-end of the drill bit and punch a hole through the center of the collection pan. The drill bit is then mounted through the pan and into the drill. Thus, the driller can be drilling straight up while the assistant steadies the pan to catch the falling dust. As a precaution, it may be advantageous to tape a piece of plastic around the drill, just below the chuck, to avoid dust contaminating the body of the drill and entering the mechanical vents. (Note, the plastic should deflect dust from the drill, but be loose enough underneath to allow for proper ventilation.)

7.2 Multiple Depth Concrete Sampling

The above method for concrete sampling can also be used to collect samples from different depths within the concrete. To do this, two different sized drill bits (i.e., ½ inch and 1 inch) and a simple vacuum pump with a vacuum trap assembly is required (see Figure 1). First, the 1 inch drill bit is used to drill to the first level and the concrete sample is collected as described in Section 7.1. The vacuum pump is then turned on and the hole is cleaned out using the vacuum trap assembly. The drill bit is then changed to the ½ inch bit and the next depth is drilled out (the ½ inch bit is used to avoid contact with the sides of the first hole). A clean tube or flask is placed on the vacuum trap, and the sample from the second drilling is collected. To go further, the 1 inch drill is used to open up the hole to the second level, the hole is cleared, and then the ½ inch drill is used again to go to a third level, etc. Note, the holes and concrete surface should be vacuumed thoroughly to minimize any cross-contamination between sample depths.

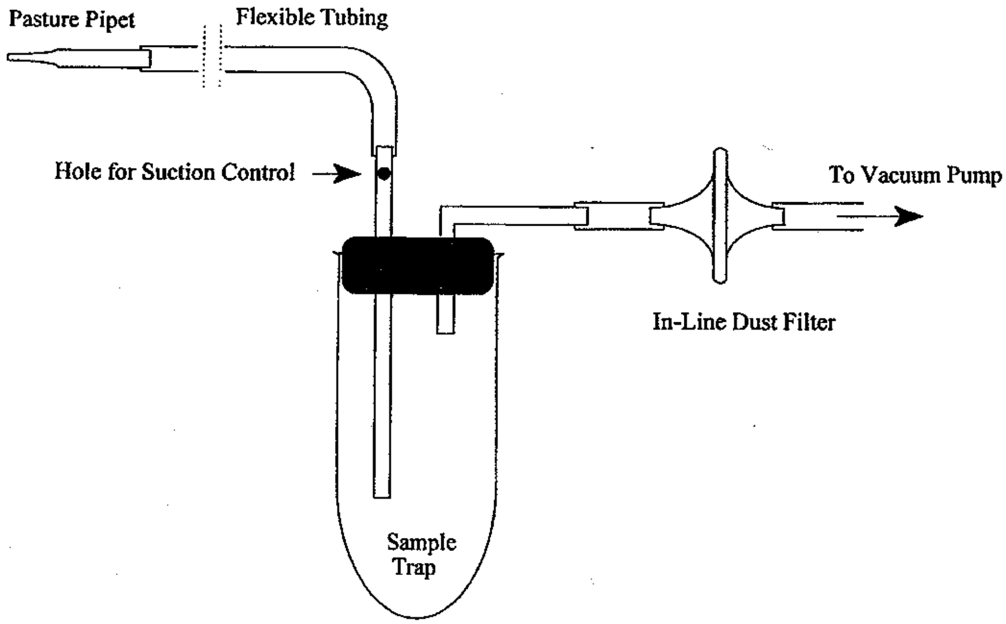
Vacuum Trap Design and Clean-out

The trap presented in Figure 1 is a convenient and thorough way for collecting and removing concrete powder from drilled holes. The trap system is designed to allow for control of the suction from the vacuum pump and easy trap clean-out between samples. Note, by placing a hole in the inlet tube (see Figure 1), a finger on the hand holding the trap can be used to control the suction at the sampling tip. Thus, when this hole is left completely open, there will be no suction, and the sampler can have complete control over where and what to sample. To change-out between samples the following steps should be taken: 1) The pasture pipet and piece of polyethylene tubing at the sample inlet should be replaced with new materials, 2) the portion of the rubber stopper and glass tubing that was in the trap should be wiped down with a clean damp paper towel (wetted with deionized water) and then dried with a fresh paper towel, 3) a clean pipe cleaner should be drawn through the glass inlet tube to remove any concrete dust present, and 4) the glass tube or flask used to collect the sample should swapped out with a clean decontaminated sample trap. Having several clean tubes or flasks on hand will facilitate change-out between samples.

7.3 Decontamination Procedure

Necessary supplies for decontamination include: two small buckets, a scrub brush, potable water, deionized water, a squirt bottle for the deionized water, and paper towels. The first bucket contains a soap and potable water solution, and the second bucket contains just potable water. Place all used drill bits and

Figure 1



utensils in the soap and water bucket. Scrub each piece thoroughly using the scrub brush. Note, the concrete powder does cling to the metal surfaces, so care should be taken during this step, especially with the twists and curves of the drill bits. Next, rinse each piece in the potable water bucket, and follow with a deionized water rinse from the squirt bottle. Place the deionized water rinsed pieces on clean paper towels and individually dry and inspect each piece. Note, all pieces should be dry prior to reuse.

8.0 Field Documentation

All Site related documentation and reports generated from concrete sampling should be maintained in the central Site file. If personal logbooks are used, legible copies of all pertinent pages must be placed in the Site file.

8.1 Field Logbooks

All field documentation should be maintained in bound logbooks with numbered pages. If loose-leaf logsheets are used to document site activities, extra care should be taken in keep track of all logsheets. The original copy of all logsheets should be maintained in the central Site file. Note, all sample locations must be documented by tying in their location to a detailed site map, or by using two or more permanent landmarks. The following information should be documented in the field logbooks:

- Site name and location,
- EPA Site Manager,
- Name and affiliation of field samplers (EPA, Contractor company name, etc.),
- Sampling date,
- Sample locations and IDs,
- Sampling times and depths, and
- Other pertinent information or comments

8.2 Sample Labeling and Chain-of-Custody

8.2.1 Sample Labels

Sample labels will be affixed to all sample containers. Labels must contain the following information:

- Project name,
- Sample number, and/or location
- Date and time of sampling,
- Analysis,
- Preservation, and
- Sampler's name.

8.2.2 Chain-of-Custody

All samples must be traced from collection, to shipment, to laboratory receipt and laboratory custody. The Chain-of-Custody (COC) Record is a multi-part form that is initiated as samples are acquired and accompanies a sample (or group of samples) as they are transferred from person to person. The COC form is signed by all individuals responsible for sampling, sample transport, and laboratory receipt. (Note, overnight deliver services, often used with sample transport, are exempt from having to sign the COC form. However, copies of all shipping invoices must be kept with the COC documentation.) One copy of the COC is retained by the field sampling crew, while the original (top, signed copy) and remaining carbonless copies are placed in a zip-lock bag and taped to the inside lid of the shipping cooler. If multiple coolers are required for a sample shipment to a single laboratory, the COC need only be sent with one of the coolers. The COC should state how many coolers are included with the shipment. All sample shipments to different laboratories require individual COC forms. The original COC form accompanies the samples until the project is complete, and is then kept in the permanent project file. A copy of the COC is also kept with the project manager, the laboratory manager, and attached to the data package.

8.2.3 Custody Seal

The Custody seal is an adhesive-backed label which is also part of the chain-of-custody process. The custody seal is used to prevent tampering with the samples after they have been collected in the field and sealed in coolers for transit to the laboratory. The Custody seals are signed and dated by a sampler and affixed across the opening edges of each cooler containing samples. Clear packing tape should be wrapped around the cooler, and over the Custody seal, to secure the cooler and avoid accidental tampering with the Custody seal.

9.0 Quality Assurance and Quality Control (QA/QC)

A solid QA/QC program is essential to establishing the quality of the data generated so that proper project decisions can be made. The following are key quality control elements which should be incorporated into a concrete sampling and analytical program.

9.1 Equipment Blanks

An equipment blank should be performed on decontaminated drill bits and collection utensils at a frequency of 1 per 20 samples or 1 per day, whichever is greater. To prepare the equipment blank, place the decontaminated drill bit and utensils in a large clean stainless steel bowl. Pour sufficient deionized water into the bowl to fill all of the required sample containers. Next, stir the drill bit and utensils in the bowl with a clean utensil to thoroughly mix the blank. Finally, decant off the equipment blank into the sample containers. Note, a clean funnel may help to pour off the equipment blank into the containers.

9.2 Field Duplicates

Field duplicates are samples collected adjacent to each other (collocated) at the same sample location (not two aliquots of the same sample). Field duplicates not only help provide an indicator of overall precision, but measure the cumulative effects of both the field and analytical precision, and also measure the representativeness of the sample. Field duplicates must be prepared and analyzed at a frequency of 1 per 20 samples or 1 per non-related concrete matrix, whichever is greater. An example of a non-related concrete matrix might be the investigation of two different types of chemical spills.

Calculate the Relative Percent Difference (RPD) between the sample and its duplicate using Equation 1.

Equation 1

$$RPD = \frac{|S - D|}{\frac{(S + D)}{2}} x\ 100$$

Where:

S = Original sample result
D = Duplicate sample result

The following general guidelines have been established for field duplicate criteria:

- If both the original and field duplicate values are ≥ practical quantitation limit (PQL), then the control limit for RPD is ≤50%,
- If one or both values are < PQL, then do not assess the RPD.

If more rigorous field duplicate criteria are needed to achieve project DQOs, then that criteria should be documented in the project QAPP.

If the field duplicate criteria specified above are not met, then flag that target element with an "*" on the final report for both the original and field duplicate samples. Report both the original and field duplicate analyses; do not report the average. Field duplicate samples should be indicated on the sample ID. For example, the sample ID can contain the suffix "FD."

9.3 Laboratory Duplicates

Laboratory duplicates are two aliquots of the same sample that are prepared, homogenized and analyzed in the same manner. (Note, proper sample homogenization is critical in producing meaningful results.) The precision of the sample preparation and analytical methods is determined by performing a laboratory duplicate analysis. Laboratory duplicates can be prepared in the field and submitted as blind samples, or the laboratory can be requested to perform the laboratory duplicate analysis. In the case of laboratory prepared duplicates, the field sampling team must be sure to provide sufficient sample volume. Laboratory duplicates must be prepared and analyzed at a frequency of 1 per 20 samples or 1 per non-related concrete matrix, whichever is greater.

Calculate the RPD between the sample and its duplicate using Equation 1. The following general guidelines have been established for laboratory duplicate criteria:

- If both the original and laboratory duplicate values are ≥ PQL, then the control limit for RPD is ≤25%,
- If one or both values are < PQL, then do not assess the RPD.

If duplicate criteria are not met, then flag that target element with an "*" on the final report for both the original and duplicate samples. Report both the original and duplicate analyses; do not report the average.

9.4 Matrix Spike/Matrix Spike Duplicate Samples

Matrix spike/matrix spike duplicate samples (MS/MSDs) are two additional aliquots of a sample which are spiked with the appropriate compound(s) or analyte(s) of concern and then prepared and analyzed along with the original sample. (Note, proper sample homogenization, prior to spiking, is critical in producing meaningful results.) MS/MSDs help evaluate the effects of sample matrix on the analytical methods being used. The field sampling team must provide sufficient sample volume such that the field or fixed laboratory can prepare and analyze MS/MSDs at a frequency of 1 per 20 samples or 1 per non-related concrete matrix, whichever is greater.

Calculate the recovery of each matrix spike compound or analyte using Equation 2.

Equation 2

$$MSR = \frac{SSR - SR}{SA} x\ 100$$

Where,

MSR	=	Matrix Spike Recovery,	SA	=	Spike Added
SSR	=	Spiked Sample Result,	SR	=	Sample Result

Calculate the relative percent difference (RPD) between the recoveries of each compound or analyte in the matrix spike and matrix spike duplicate using Equation 3.

Equation 3

$$RPD = \frac{| MSR - MSRD |}{\frac{(MSR + MSRD)}{2}} x\ 100$$

Where,

MSR = Matrix Spike Recovery
MSRD = Matrix Spike Duplicate Recovery

9.5 Performance Evaluation Samples

In accordance with the EPA Region I Performance Evaluation Program Guidance, performance evaluation (PE) samples should be submitted for each type of analysis to be performed in the field or by the fixed laboratory performing full protocol EPA methods. PE samples provide information on the quality of the individual data packages. PE samples are certified standard reference materials (SRMs) from a source other than that used to calibrate the instrument. If both field and fixed laboratories are being used to analyze samples, at least one solid PE sample should undergo both field analysis and confirmatory full protocol EPA method analysis to facilitate data comparability. A copy of the certified values for the SRM must be submitted with the final data packages to facilitate data evaluation.

9.6 Data Verification and Validation

All field data and supporting information (including chain-of-custody) that is collected during a concrete sampling episode should be verified daily, by a person other than that performing the work, to check for possible errors.

During the project planning process, a plan for data validation should be established for all data, both for field and fixed laboratories. All data must be validated to assure that it is of a quality suitable to make project decisions. For help in developing a data validation program refer to Region I, EPA New England, Data Validation Functional Guidelines for Evaluating Environmental Analyses.

9.7 Audits

9.7.1 Internal Audits

As part of the Quality Assurance/Quality Control Program for any sampling project, a series of internal audit checks should be instituted to monitor and maintain the integrity of the sample collection process. Timely internal reviews will insure that proper sampling, decontamination, chain-of-custody and quality control procedures are being followed. Also, the internal audit review is there to monitor any corrective actions taken, and/or institute corrective actions that should have been taken and were not. All corrective actions taken must be documented in an appropriate logbook, and if any corrective actions impact the final data reported, then they must also be documented in the final report narrative. The results of all internal audits must be documented in a report, and copies of the report issued to the Project Manager and the Quality Assurance Manager. The original copy of any audit report must remain with the main project file and be available for review.

9.7.2 External Audits

The Agency reserves the right to perform periodic field audits to ensure compliance with this SOP.

10.0 References

1) Guidance for the Data Quality Objective Process, QA/G-4, EPA/600/R-96/055, September 1994.

2) EPA Requirements for Quality Assurance Project Plans for Environmental Data Operations, QA/R-5, Interim Final, October 1997.

3) Guidance for the Preparation of Standard Operating Procedures for Quality-related Operations, QA/G-6, EPA/600/R-96/027, November 1995.

4) Region I, EPA-New England Data Validation Functional Guidelines for Evaluating Environmental Analyses, July 1996.

5) EPA Region I Performance Evaluation Program Guidance, July 1996.

6) U.S. EPA Code of Federal Regulations, 40 CFR, Part 136, Appendix B, Revised as of July 1995.